AD-753 341

MOORING SITE SURVEY EQUIPMENT

Kenneth R. Bitting

Army Mobility Equipment Research and Development Center
Fort Belvoir, Virginia

September 1972

DISTRIBUTED BY:

NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

Report 2035

MOORING SITE SURVEY EQUIPMENT

by

1LT Kenneth R. Bitting

September 1972

Approved for public release; distribution unlimited.

U. S. ARMY MOBILITY EQUIPMENT RESEARCH AND DEVELOPMENT CENTER
FORT BELVOIR, VIRGINIA

Destroy this report when no longer needed. Do not return it to the originator.

The citation in this report of trade names of commercially available products does not constitute official endorsement or approval of the use of such products.

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) U. S. Army Mobility Equipment Research and Development Center Fort Belvoir, Virginia	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

MOORING SITE SURVEY EQUIPMENT

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Interim, Dec 1970–June 1972

5. AUTHOR(S) (First name, middle initial, last name)

Kenneth R. Bitting, 1LT, CE

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
September 1972	~~174~~ 178	

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO.	2035
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. DISTRIBUTION STATEMENT
Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	USAMERDC Fort Belvoir, Virginia

13. ABSTRACT

The U. S. Army Mobility Equipment Research and Development Center has developed Mooring Site Survey Equipment as part of the Multi-Leg Tanker Mooring System. The mission of Mooring Site Survey Equipment is to survey the ocean bottom and sub-bottom at a prospective mooring site and: (a) Locate submerged objects that are navigational hazards to ships and lifters operating in or around moorings. (b) Determine the suitability of the sediment for the deployment of the USAMERDC XM-50 and XM-200 Explosive Embedment Anchor (EEA). (c) Provide a continuous water depth record in the mooring. (d) Determine profile of bottom from shore to mooring site to determine suitability for installation of submarine pipeline.

The components of Mooring Site Survey Equipment are: (a) Acoustic Underwater Survey Equipment (AUSE), which remotely detects sediment interfaces within the sediment and objects on the ocean bottom using acoustic energy. (b) Explosive Embedment Penetrometer (EEP), which determines the suitability of ocean bottom sediments at a particular location for the deployment of the USAMERDC XM-50 and XM-200 Explosive Embedment Anchors by propelling a projectile into the ocean floor.

The AUSE, a combination side scan sonar and sub-bottom profiler, is initially deployed at a mooring site to detect submerged and protruding objects and determine the general sediment composition. Eliminating those areas not suitable for the EEA, the EEP is deployed at the exact location where an EEA is to be fired. The EEP fires a projectile into the ocean floor and measures the penetration and force required to extract it. The penetration and extraction forces of the EEP are correlated to the penetration and holding power of the USAMERDC XM-20 and XM-200 EEAs.

Testing and development of this equipment is discussed.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

UNCLASSIFIED
Security Classification

UNCLASSIFIED
Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT

1B

UNCLASSIFIED
Security Classification

U. S. ARMY MOBILITY EQUIPMENT
RESEARCH AND DEVELOPMENT CENTER
FORT BELVOIR, VIRGINIA

Report 2035

MOORING SITE SURVEY EQUIPMENT

Tasks 1J664717DL4101 and 2

September 1972

Distributed by

The Commanding Officer
U. S. Army Mobility Equipment Research and Development Center

Prepared by

1LT Kenneth R. Bitting
Fuels Handling Equipment Division
Mechanical Technology Department

_ic_

SUMMARY

The U. S. Army Mobility Equipment Research and Development Center has developed Mooring Site Survey Equipment as part of the Multi-Leg Tanker Mooring System. The mission of Mooring Site Survey Equipment is to survey the ocean bottom and sub-bottom at a prospective mooring site and:

a. Locate submerged objects that are navigational hazards to ships and lighters operating in or around moorings.

b. Determine the suitability of the sediment for the deployment of the USAMERDC XM-50 and XM-200 Explosive Embedment Anchor (EEA).

c. Provide a continuous water depth record in the mooring.

d. Determine profile of bottom from shore to mooring site to determine suitability for installation of submarine pipeline.

The components of Mooring Site Survey Equipment are:

a. Acoustic Underwater Survey Equipment (AUSE), which remotely detects sediment interfaces within the sediment and objects on the ocean bottom using acoustic energy.

b. Explosive Embedment Penetrometer (EEP), which determines the suitability of ocean bottom sediments at a particular location for the deployment of the USAMERDC XM-50 and XM-200 Explosive Embedment Anchors by propelling a projectile into the ocean floor.

The AUSE, a combination side scan sonar and sub-bottom profiler, is initially deployed at a mooring site to detect submerged and protruding objects and determine the general sediment composition. Eliminating those areas not suitable for the EEA, the EEP is deployed at the exact location where an EEA is to be fired. The EEP fires a projectile into the ocean floor and measures the penetration and force required to extract it. The penetration and extraction forces of the EEP are correlated to the penetration and holding power of the USAMERDC XM-50 and XM-200 EEAs.

Testing and development of this equipment is discussed, and it is concluded that:

a. Mooring Site Survey Equipment can determine the suitability of an offshore area for the deployment of the Multi-Leg Tanker Mooring System. The AUSE and EEP

complement each other to achieve the mission with a degree of accuracy and reliability that is not equaled by the deployment of one of the components alone.

b. The combination of a sub-bottom profiler and side scan sonar is far more valuable than either alone. The side scan sonar aids in the identification of the surface sediments on the sub-bottom profiler.

c. The side scan sonar can identify manmade objects, natural terrain features and ocean bottom surface sediment characteristics.

d. The sub-bottom profiler can detect discrete sediment layers approximately 1 foot in thickness.

e. The sub-bottom profiler can determine the general sediment type of the ocean floor and can distinguish between sand, rock, mud, and clay.

f. Limited testing has shown that enlisted personnel of MOS 51C with proper training and sufficient experience can operate the AUSE.

g. A correlation exists between the penetration and extraction force of the EEP and the penetration and holding power of the USAMERDC XM-200/XM-50 EEA.

h. The Mooring Site Survey Equipment can be deployed from a 25-foot Coast Guard Motor Surfboat in light seas.

FOREWORD

Authority for design, fabrication, and testing of Mooring Site Survey Equipment is contained in Task 1J664717DL4101, "Marine Terminals".

Design and fabrication of the major components were accomplished under contracts by the Environmental Equipment Division of EG&G (DAAK02-71-C-0410) and Magnavox Systems, Inc. (DAAK02-71-C-0274). The design and fabrication of the ancillary components were accomplished at USAMERDC under the direction of William S. Guerrant, Chief of Construction and Marine Systems Branch, Fuels Handling Equipment Division, USAMERDC. The following USAMERDC personnel have been active in the development of Mooring Site Survey Equipment: 1LT Kenneth R. Bitting, SP4 David J. Kramer, and SP4 Duane Braun.

CONTENTS

CONTENTS (cont'd)

CONTENTS (cont'd)

ILLUSTRATIONS

ILLUSTRATIONS (cont'd)

ILLUSTRATIONS (cont'd)

TABLES

SYMBOLS

A	Profiler area of the EEP wire rope.
B	Beam width of side scan sonar.
C	Serve cable length.
C_D	Coefficient of drag.
C_L	Coefficient of lift.
d	Water depth.
D_a	True distance (or length) in the direction parallel to the direction of the vessel's motion.
d_H	Horizontal component of drag.
d_i	Water depth indicated on sub-bottom profiler record.
d_L	Lateral distance from a point below the vessel to the target.
d_r	Radial distance to a target from the side scan sonar transducer.
D_r	True distance in the direction perpendicular to the vessel's path (range and direction).
d_v	Vertical component of drag.
F_G	Force exerted on gunstand by wire rope.
g	Acceleration due to gravity.
h	Height of object on ocean floor.
H	Height of side scan sonar above the ocean bottom.
H_1	Distance from the bottom of the gunstand to the shear pin block.
I	Image dimension on the record.

SYMBOLS (cont'd)

L_g	Length on the ground traversed in time, t.
L_r	Length on the record traversed in time, t.
ℓ_s	Shear pin failure depth.
L_T	Length of oblique target.
$L_1 - L_2$	Components of length.
ℓ	Depth of sub-bottom layers.
P	Penetration of EEP projectile into ocean floor.
P_v	Vertical depth of projectile.
R	Radial distance to target.
r	Length of acoustic shadow.
R_1	Footage counter reading at first indication of load.
R_2	Footage counter reading at termination of load.
R'	Footage counter reading at interface.
R_r	Rate at which paper moves out of recorder.
R_s	Range scale.
R'_s	Shear pin failure footage counter reading.
S	Spot size.
S_p	Distance between hydrophone and pinger probe.
t	Time.

SYMBOLS (cont'd)

T'	Tension.
T	Side scan transducer depth.
V	Velocity of water current.
V_g	Velocity of vessel over the ocean floor
w	Weight per unit length of wire rope.
W_1, W_2	Components of width.
w_T	Width of an oblique target.
x	Horizontal excursion of the gunstand from a point directly below the stern of the MSB.
α	Angle of EEP wire rope.
α_i	Angle between wire rope and the horizontal at the gunstand.
ϕ	Angle of incidence of the penetrometer on the ocean bottom.
λ	Water length.
ρ	Density of seawater.

MOORING SITE SURVEY EQUIPMENT

I. INTRODUCTION

The U. S. Army Mobility Equipment Research and Development Center (USAMERDC), Fort Belvoir, Virginia, is developing the Multi-Leg Tanker Mooring System consisting of a tactical, air-transportable mooring-construction system, and a deliberate mooring system installable with conventional marine construction equipment.

The construction time and air-transportability weight limitations necessitate the use of explosive embedment anchors rather than the common chain and anchor type mooring.

The XM-50 Explosive Embedment Anchor (EEA) developed for this system by USAMERDC is deployed most reliably in sands and clays, will not hold in mud, and cannot penetrate rock. This necessitates the elimination of prospective mooring sites that have undesirable characteristics. This is the mission of Mooring Site Survey Equipment.

Mooring Site Survey Equipment (MSSE) is composed of two components: Acoustic Underwater Survey Equipment (AUSE) and Explosive Embedment Penetrometer (EEP).

Acoustic Underwater Survey Equipment is a combination side scan sonar and sub-bottom profiler. The side scan sonar detects manmade and natural obstructions on the ocean floor that might damage a tanker as it approaches the mooring. The sub-bottom profiler gives a general indication of the sediment suitability for the deployment of the EEA. It also gives a continuous water depth record in the mooring.

Once the AUSE has identified areas that appear to be suitable for the mooring, the EEP is deployed at the exact locations where the explosive embedment anchors are to be fired. The EEP is lowered from a 25-foot Coast Guard Motor Surf Boat (MSB) and fires a projectile into the ocean floor. The force required to extract the projectile and the penetration of the projectile into the ocean floor are measured. From this information, the potential holding power of the XM-50 EEA can be predicted. Whereas the AUSE detects the ocean floor remotely, the EEP provides a "physical handle" on the sub-bottom soil characteristics.

II. ACOUSTIC UNDERWATER SURVEY EQUIPMENT

A. Concept

1. General Description. The mission of the AUSE is to survey the ocean floor at a mooring site and determine by acoustic means its suitability for the deployment of the USAMERDC XM-50 EEA. It accomplishes this in three ways:

a. By determining general sediment composition up to 50 feet below the ocean floor and identifying areas not suitable for the deployment of the EEA. The two conditions limiting the use of the EEA are sediments too soft to permit the EEA to develop adequate holding power, and rock bottoms into which the EEA cannot penetrate.

b. By locating manmade obstacles and natural features (e.g., sunken vessels and rocks) on the ocean floor which are navigational hazards to vessels or lighters approaching or operating within the mooring site.

c. By providing a continuous, accurate record of the water depth throughout the mooring and in the approaches, it will identify areas in or near the mooring where the water depth is not sufficient for the operation of lighters or launches. This information will also assist in determining the maximum safe draft of a tanker (i.e., the quantity of petroleum it carries) before it is dispatched to the mooring.

2. **Sonar Concepts.** The AUSE is a combination side scan and sonar sub-bottom profiler.

a. **Sub-Bottom Profiler.** The sub-bottom profiler is a "down-looking" sonar that produces a profile of the ocean bottom sediments along a vertical plane (Fig. 1). The sub-bottom profiler consists of a sound source and a receiver.

The sound source transmits acoustic energy vertically into the ocean floor. The energy reflects off the ocean floor and returns to a waterborne receiver on the surface. The amount of energy and the time interval over which the energy is returned are indications of the general type of sediment present in the ocean floor.

In general, the penetration of the acoustic energy into the ocean floor is inversely proportioned to the frequency of the outgoing pulse. The resolution of the sediment layers is directly proportional to the frequency and is generally considered to be one-half of the wavelength of the transmitted pulse.

b. **Side Scan Sonar.** Side scan sonar "looks" across the ocean floor and detects natural and manmade objects and surface sediment characteristics. Side scan sonar does not penetrate the ocean floor.

The side scan sonar transducers are mounted in a towed body that is suspended 25 to 50 feet above the ocean floor. The transducer sends a fan-shaped pulse perpendicular to the track of the vessel and declined slightly from the horizontal (Fig. 2). The acoustic energy that reflects off the ocean floor is received by a transducer in the towed body.

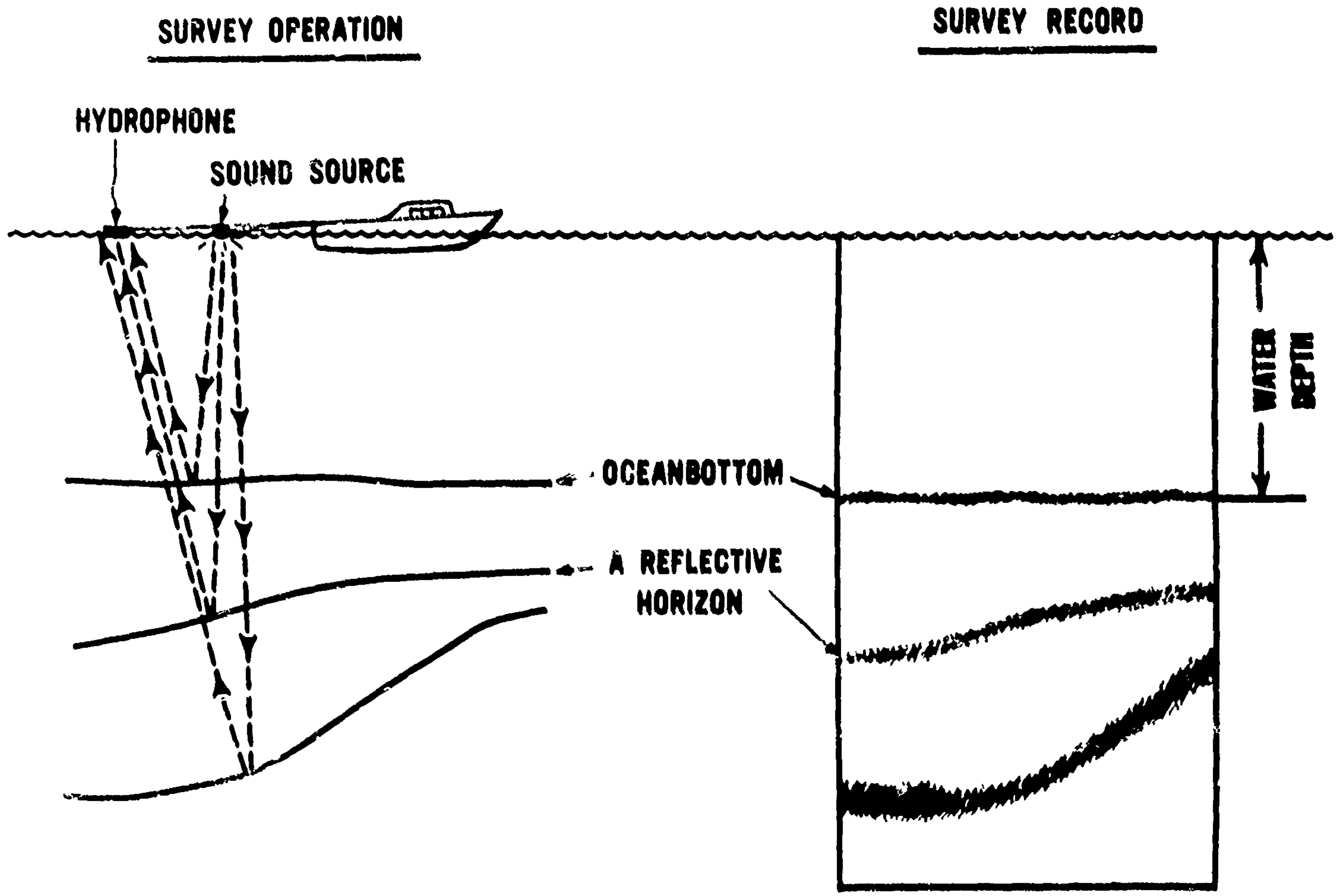


Fig. 1. Concept—acoustic sub-bottom profiling techniques.

Fig. 2. Side scan sonar concept.

Side scan sonar produces a record similar to an aerial photograph of the ocean floor. The height and length of objects can be determined from the side scan sonar record.

B. Prototype Equipment

To assess the feasibility of the application of sonar to mooring site surveys, a contract was awarded to the Environmental Equipment Division of EG&G, Waltham, Massachusetts, to fabricate the necessary equipment.

EG&G manufactures a side scan sonar and a sub-bottom profiler for commercial use. To conserve the limited space available in the MSB, the two instruments were combined into one unit. USAMERDC leased the equipment and tested it in areas that offered a variety of ocean bottom and sub-bottom conditions. The results of the tests showed that a combination side scan sonar-sub-bottom profiler was a feasible approach to the assessment of mooring site suitability.

Drawing upon the experience gained during the tests, a purchase description was derived for the second generation equipment that would meet the specific military needs of the Multi-Leg Tanker Mooring System.

C. Description of Equipment

1. **General Description.** The AUSE combines a 5-kHz sub-bottom profiling system and a dual-channel side scan sonar system sharing a common recorder (Fig. 3). The sub-bottom profiling system provides a profile of the sub-bottom sediment layers below the vessel's path. The side-scan system provides a plan view of the ocean bottom on both sides of the vessel's path. All equipment is powered by two 12-volt batteries in series.

The basic system is shown in Fig. 4 and consists of a side scan sonar towed body, a sub-bottom profiling sound source and hydrophone, and a dual-channel recorder. The side scan sound source and receiver are within the towed body. The sub-bottom profiler employs separate sound source and receiver.

2. **General Specifications.** The AUSE was designed to be operated by two men on a 25-foot Coast Guard Motor Surf Boat (MSB) at some speed between 3 and 6 knots in water depths between 25 and 150 feet at a sea state two or calmer conditions, with ambient temperatures between 25° F and 125° F, and using two or less storage batteries for power. The side scan sonar transducer is designed to provide a 10-foot resolution of objects at a range of 500 feet.

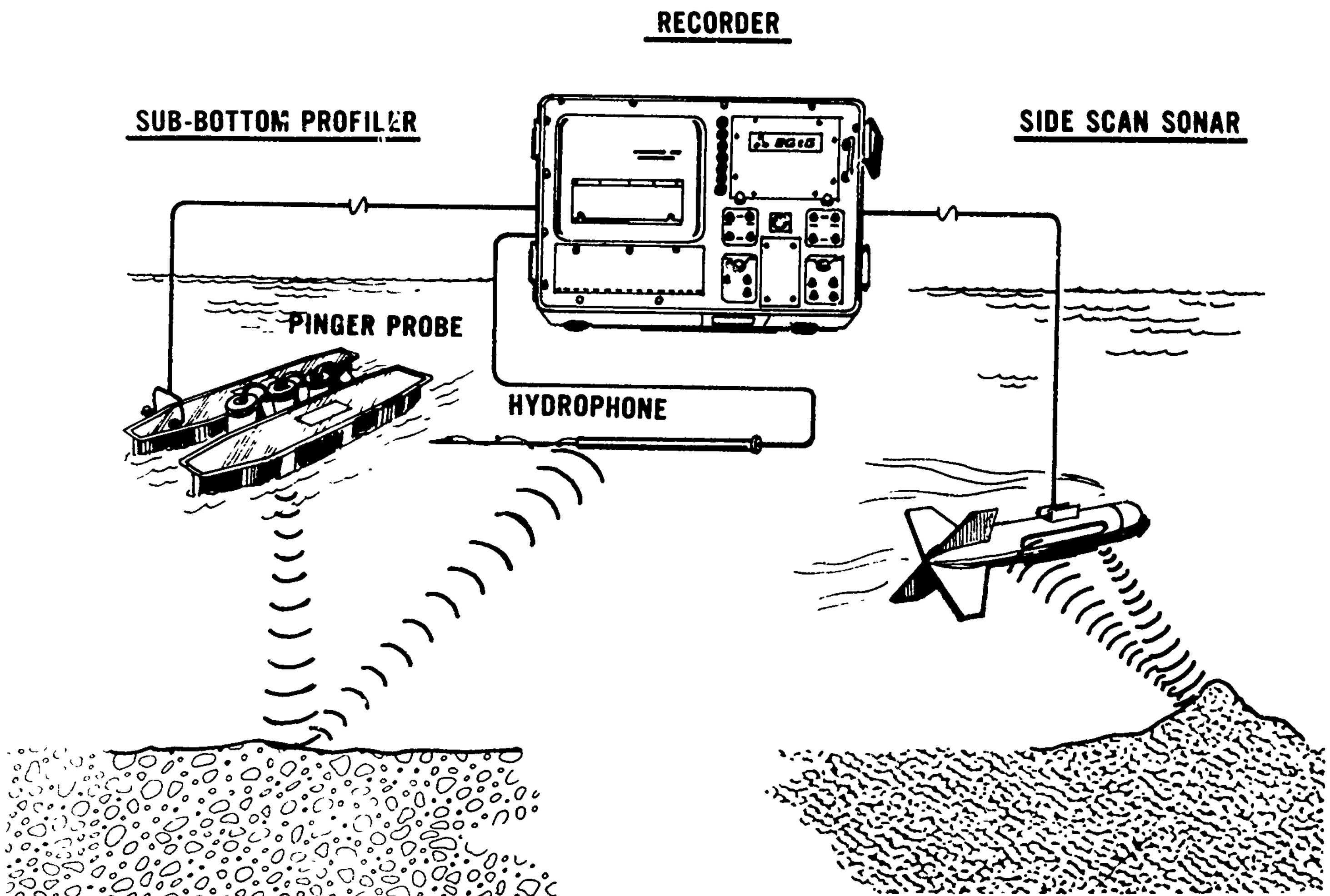


Fig. 3. Acoustic underwater survey equipment—schematic.

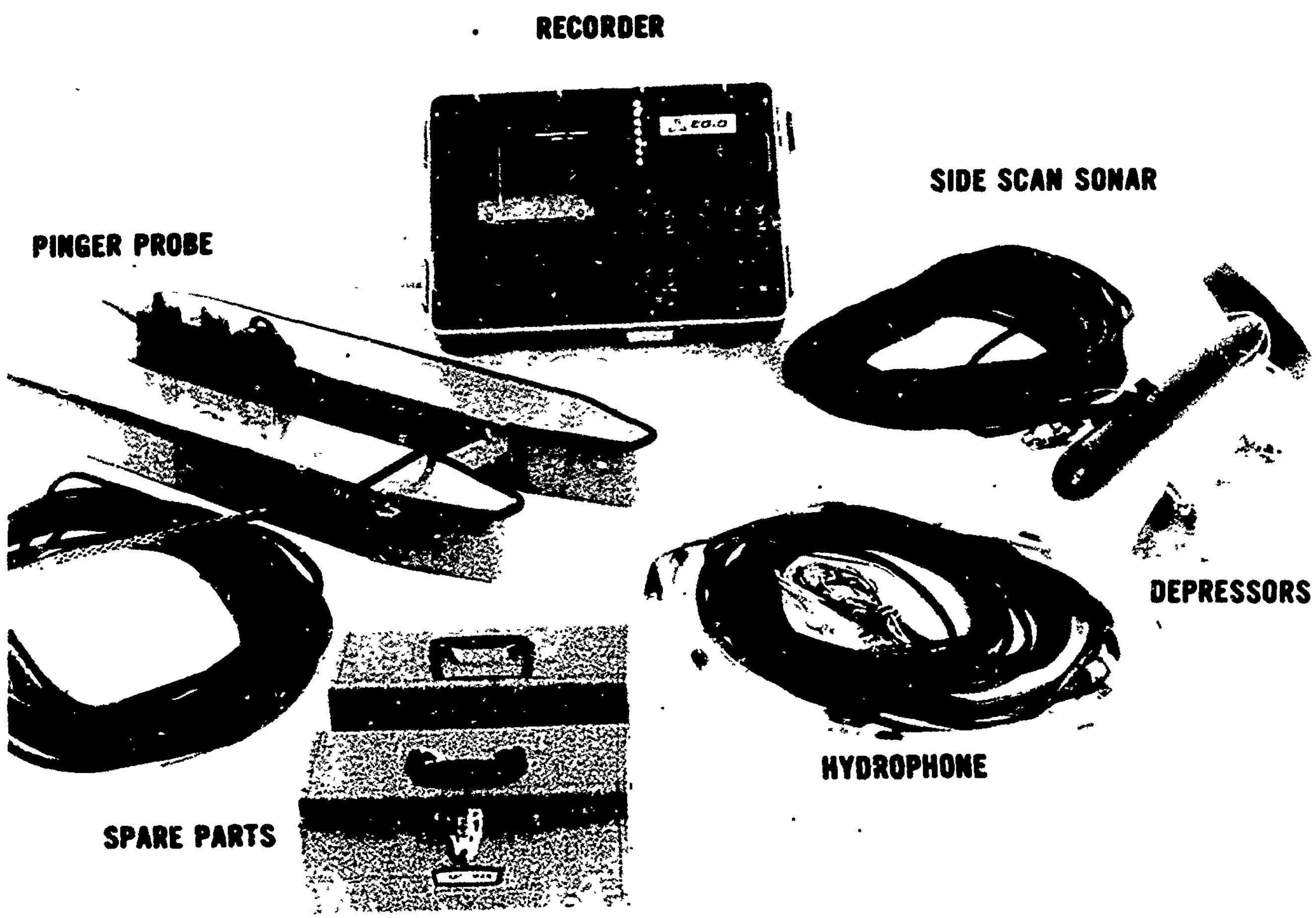


Fig. 4. Acoustic underwater survey equipment.

The sub-bottom profile is designed to determine water depths to within ± 1 percent of the true depth in 25 to 150 feet of water and to provide 50 feet of sub-bottom penetration in mud and silt sediments and lesser penetrations in sand and gravel. The sub-bottom profiler is capable of resolving a distinct sediment layer 1 foot in thickness.

3. **Components.**

a. **Oceanographic Recorder.**

(1) **General Description.** The oceanographic recorder is of the dual-channel continuous wet paper type. A dual-channel recorder prints two independent signals, one on each half of the 11-inch roll of chart paper. This capability allows the side scan sonar and sub-bottom profiler data to be displayed simultaneously, one on each channel.

The wet paper recording process utilizes paper that is permeated by a ferric solution. The paper turns brown as current passes through it. The darkness of the printed signal is proportional to the current passing through the paper.

The recorder contains all circuitry necessary to generate, transmit, amplify, filter, and print the acoustic signal. Nearly all components that may fail and require replacement are accessible from the front panel. The circuitry is physically grouped in two ways, by functions and by channel. In the former, the circuitry is grouped by function and placed on printed circuit boards (PCB). Since each PCB has a specific function (e.g., amplifier or generator card), repairs may be made by identifying the type of operational problem and removing and replacing that PCB while the instrument is operating. Two reserve sets of PCB are carried with the records to effect repairs. In the latter method of grouping, a major part of the circuitry for each channel is independent of the other. This allows the instrument to continue to operate even if difficulties exist in one of the channels. This arrangement also facilitates the location of malfunctions by further separating the circuitry.

(2) **Circuit Diagram.** A simplified circuit diagram is shown in Fig. 5. Several PCBs (e.g., built-in test boards and relay boards) are not shown.

(a) **Sub-Bottom Profiler.** Upon receipt of a trigger pulse from the trigger/scale line generator (J3), the sub-bottom profiler (5-kHz) driver board discharges a bank of capacitors into the barium titanate ceramic transducers of the pinger probe. The electric pulse causes the transducer to expand

rapidly and produce a pulse of acoustic energy. The clicking sound can be heard by the human ear.

The acoustic pulse travels through the water column, reflects off the ocean floor and sediment interfaces, and returns to the water's surface where it is received by the hydrophone. The sub-bottom profiler signal amplifier (J9) receives the signal from the hydrophone and filters and amplifies it to a level that will drive the print amplifier (J1, J2). The print amplifier raises the voltage and current to a level sufficient to cause writing to appear on the paper. The print amplifier also produces the event marker.

An adjustment in the print amplifier, called the threshold, eliminates extraneous noise that is received from the water by the hydrophone. It may be necessary to make this adjustment when operating from vessels with different noise levels.

The filtered and amplified signal is conducted to the helix strip through a commutator brush in the end of the drum. The current passes from the helix strip through the paper and into the endless electrode, called the helix blade, to ground. As the drum turns, the helix strip contacts the endless electrode at a point which sweeps from the center of the drum outward, and the current passes through the paper to ground.

The total image on the paper is a composite of many lines next to one another.

(b) Side Scan Sonar. Upon receipt of the trigger pulse, the side scan driver card (J4) sends a pulse to the towed body referred to as the "fish." *Caution:* The side scan driver card should not be removed or otherwise adjusted while the instrument is in operation, because 750 volts are present on this board.

Transducers on both sides transmit a fan-shaped beam (Fig. 2). The signal returning from a target is received by a separate transducer. The signal received by each channel is amplified and filtered by the side scan amplifier card for that channel (J8, J9). The processed signal is amplified further and printed by the print amplifier for that channel (J1, J2).

Scale lines are printed on the chart paper to provide a special reference. They are generated by the trigger/scale line generator (J3). The generator is triggered once each revolution by a flash of light that passes through a hole in the cog belt wheel on the end of the helix drum axle.

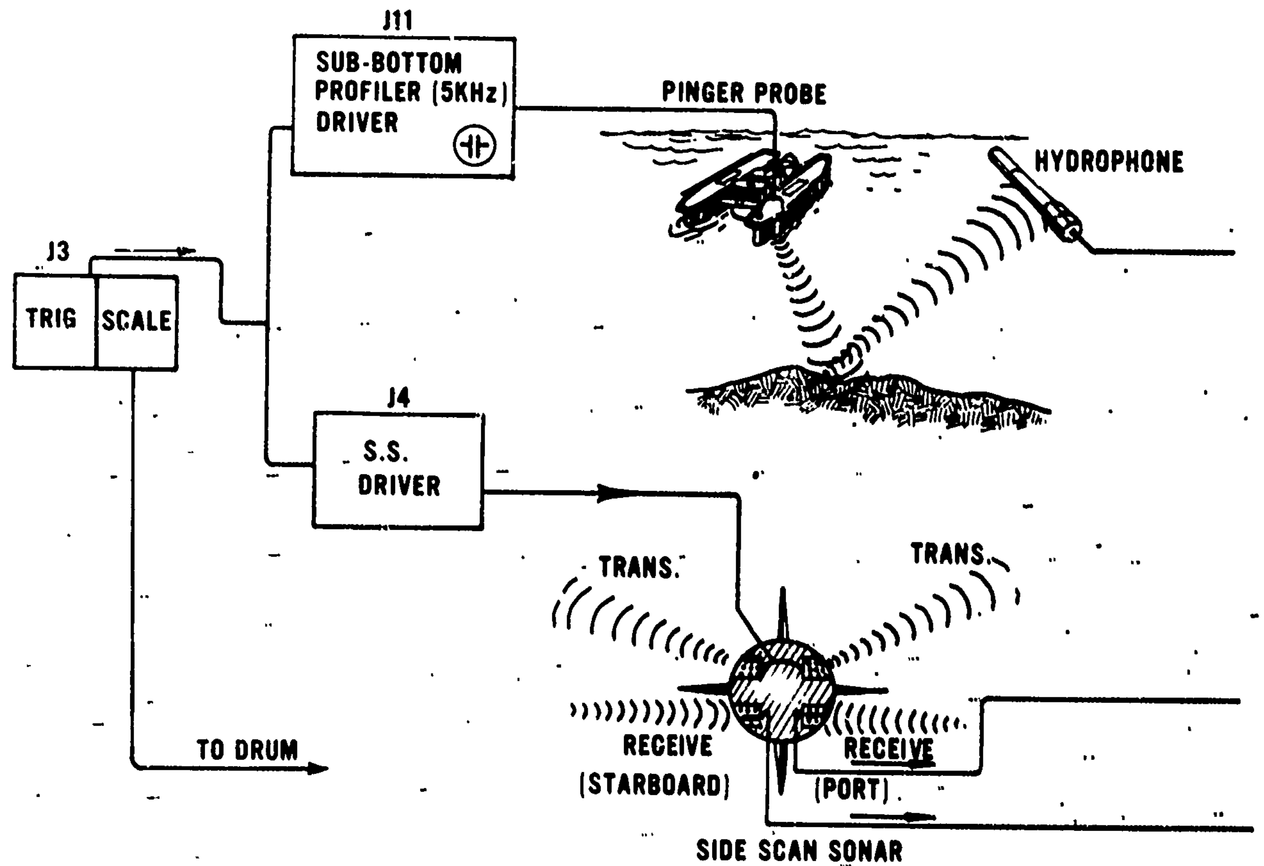
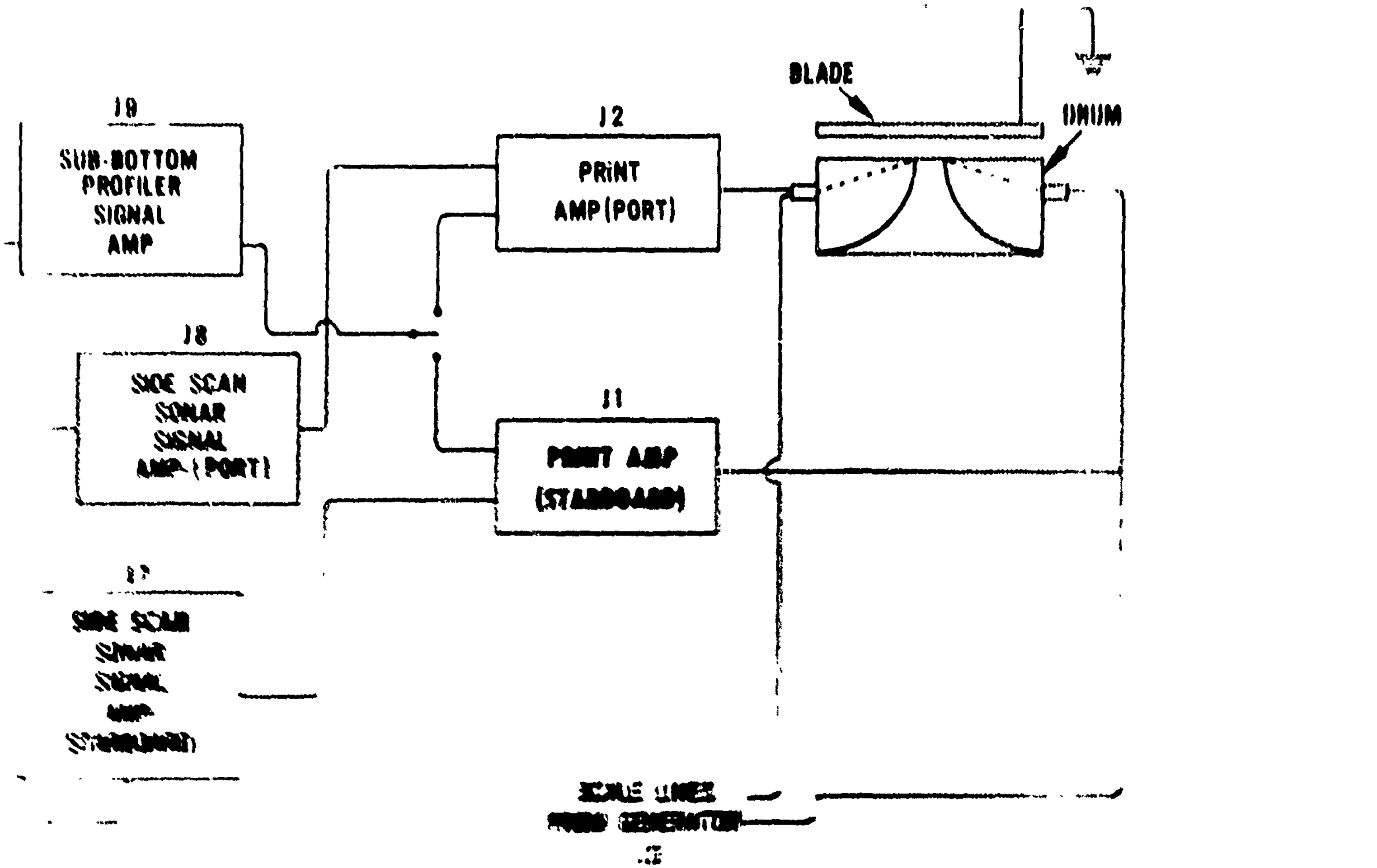


Fig. 5. Circuit diagram.


J9
SUB-BOTTOM PROFILER SIGNAL AMP
J8
SIDE SCAN SONAR SIGNAL AMP (PORT)
SIDE SCAN SONAR SIGNAL AMP (STARBOARD)
J2
PRINT AMP (PORT)
J1
PRINT AMP (STARBOARD)
BLADE
SCALE LINES

(3) **Printing Mechanism.** The printing mechanism is located on the left half of the recorder. It consists of the helix drum, helix blade, paper drive rollers, paper take-up reel, and paper compartment.

(a) **Paper Compartment.** A fresh roll of paper is placed in the paper compartment behind the helix drum. A small damp sponge is placed under the paper to keep it moist. Ambient heat or heat generated by the electronic components can cause the paper to dry slightly and the printing will appear somewhat faded.

The paper is drawn over the helix drum and paper drive rollers and slipped into the paper take-up compartment through a slot in the top panel. When the lid is down (Fig. 6) and the equipment is operating, the paper does not leave the spray-proof recorder and is therefore not subjected to salt-water spray.

(b) **Paper Drive Rollers.** The paper drive rollers pull the paper out of the paper compartment and between th helix drum and helix blade in the lid (shown in raised position in Fig. 7). The rollers are driven by a belt from the same motor that drives the helix drum and paper take-up reel.

(c) **Paper Take-Up Reel.** After the paper passes between the helix drum and helix blade and is printed upon, it is taken up on a reel in a splash-proof compartment in the front of the recorder. The reel is driven at the same rate as the paper drive rollers. A clutch mechanism applies a slight tension to the paper to insure that it rolls onto the reel evenly and permits the reel to be turned backward so that the records can be reviewed while the instrument is operating.

The door to the compartment is gasketed so that no water can enter the compartment and damage the records, since exposing these records to spray damages them severely. This feature is a major improvement over the prototype system and permits all-weather operation. In a dry environment, the door can be opened and the roll taken out and the records reviewed during operation.

(d) **Helix Drum.** The helix strip (on the helix drum) sweeps a point of electrical contact across the paper. There is one helix strip for each channel.

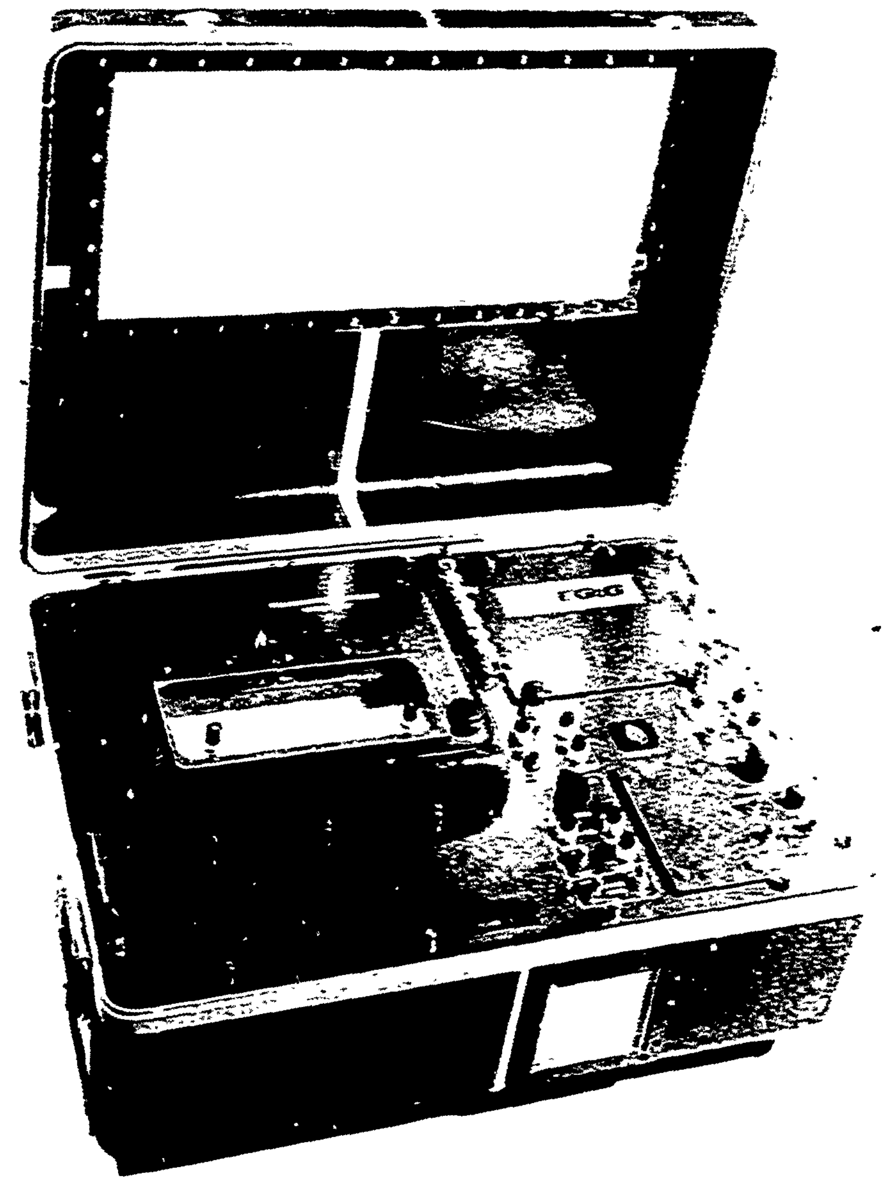


Fig. 6. Oceanographic recorder. T11823

The current passes through the paper into the endless electrode called the helix blade. The helix blade is rotated slowly to distribute the wear evenly.

The pressure between the helix strip and the helix blade is adjusted by thumb screws (Fig. 7).

(c) Lid. The lid holds the helix blade assembly, which is spring loaded so that the same pressure will be applied to the helix strip by the helix blade, regardless of how tightly the lid is tightened.

The lid has four lightbulbs to illuminate the record as it is produced. The light intensity is controlled by the lamp switch on the right side of the control panel. The lightbulbs are spring-mounted to avoid damage from shock and vibration.

A hinged window on the lid (Fig. 6) can be opened to facilitate marking the records. The lid and window are gasketed to form a splash-proof cover over the paper.

(4) Controls.

(a) Modes of Operation. For purposes of definition, AUSE has three functions: two channels of side scan sonar and the sub bottom profiler. These functions can be combined in three modes:

Port Channel	Starboard Channel
Side scan	Side scan
Side scan	Sub-bottom profiler
Sub-bottom profiler	Side scan

(b) Mode Switch. The mode switch (Fig. 8) determines the channel on which the sub-bottom profile will be printed. When the switch is turned to the left or right the profile will print on the port or starboard channel, respectively. The side scan sonar on the opposite channel is automatically printed. The center position of the mode switch turns off the profile and the side scan sonar of both channels is printed.

(c) Function Controls. There are three sets of controls, one for each function (Fig. 8). Each function can be tuned properly at all times, even if it is not being printed. This is an improvement over the prototype

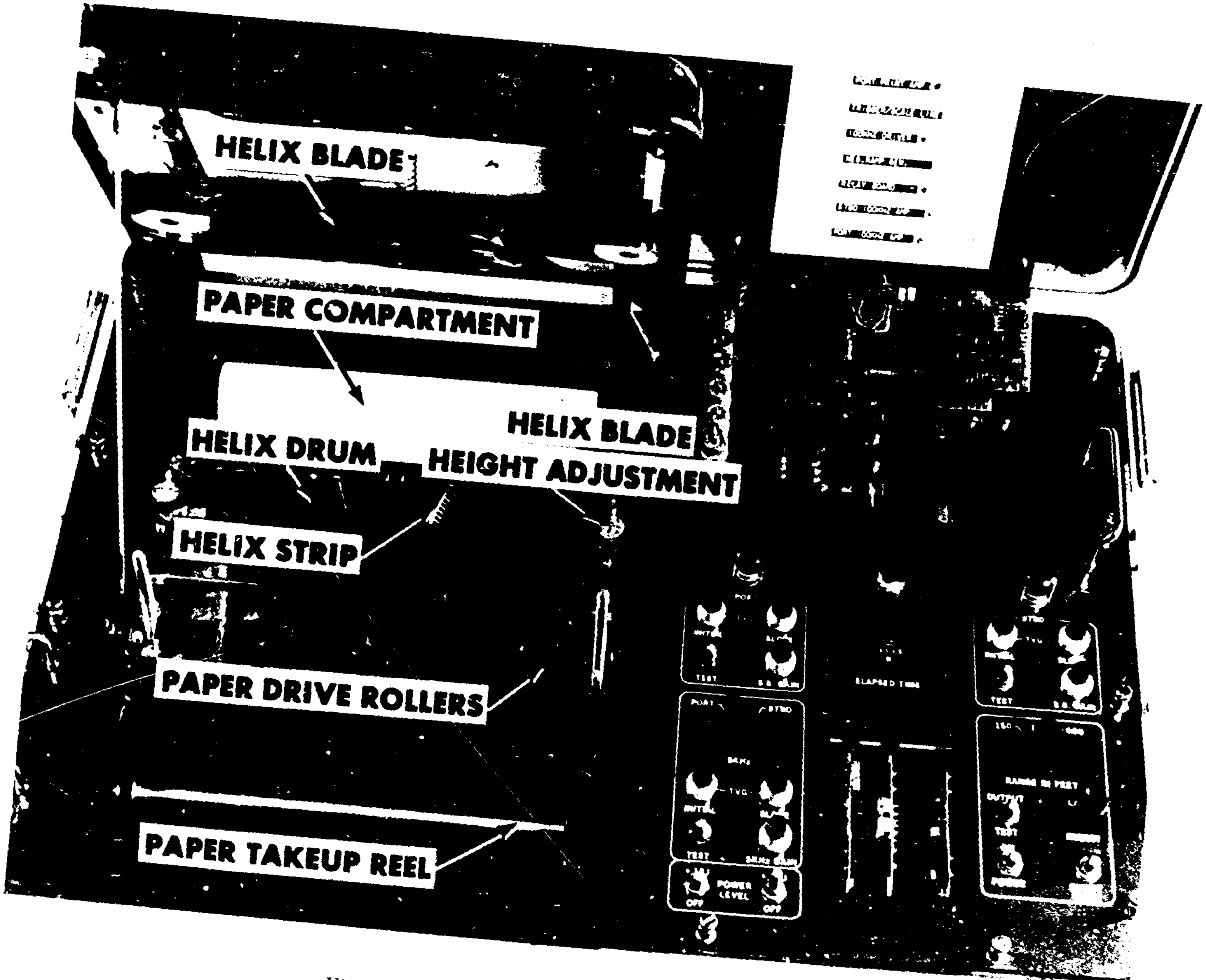


Fig. 7. Oceanographic recorder—front panel.

V5209

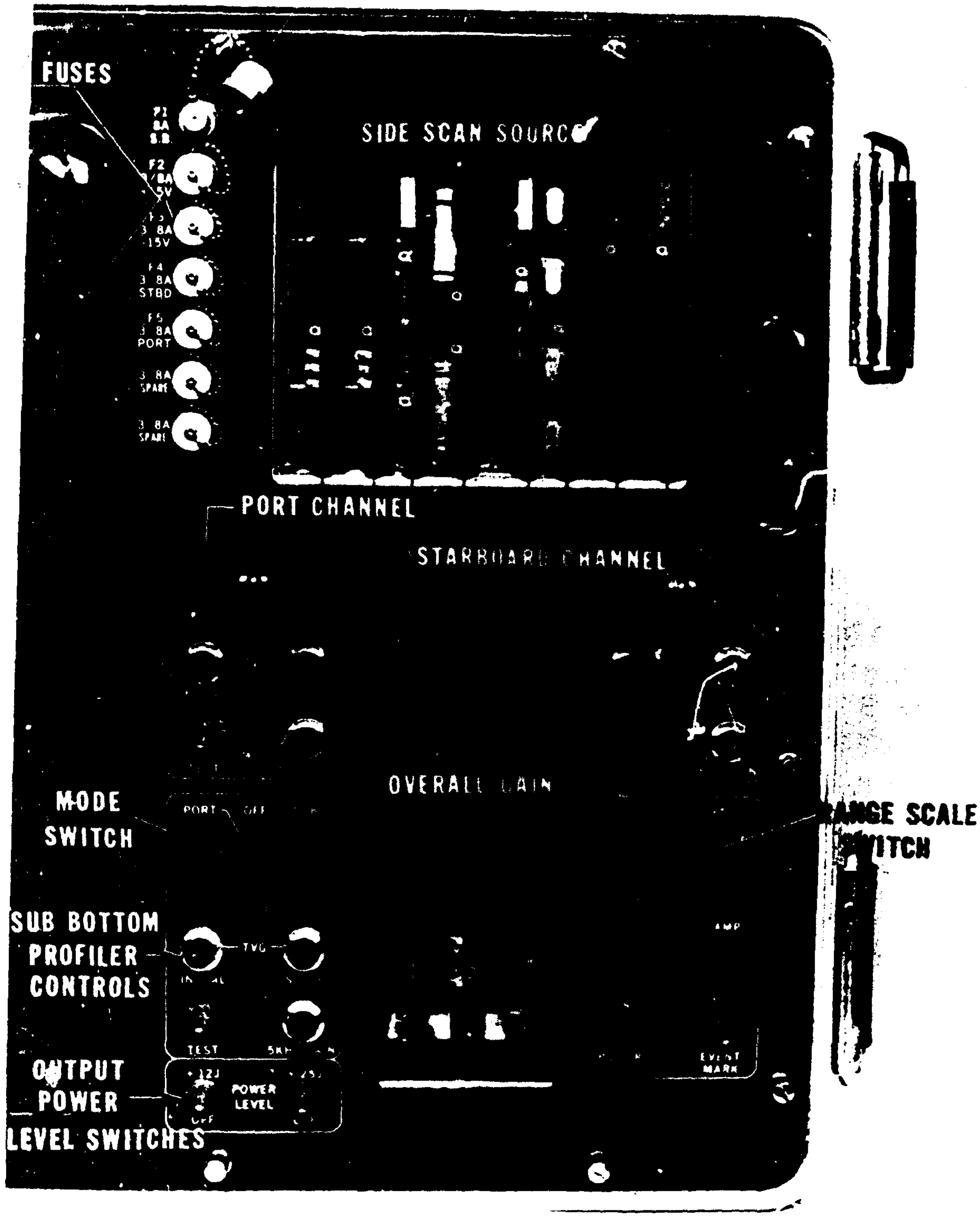


Fig. 8. Oceanographic recorder—controls.

instrument, which had only two controls (i.e., amplifiers) for the three functions.

Each time the mode switch was changed, the amplifiers had to be tuned because the gain settings of the side scan sonar and sub-bottom profiler are quite different. With the above improvement, all functions are always tuned and ready to print when the switch is turned. This is particularly helpful during a survey (paragraph II H).

The controls for each function affect the way in which it receives the signal as it returns from the ocean bottom. The Time Varied Gain (TVG) (initial and slope in Fig. 8) and the overall gain interact so that a balance must be reached during tuning. A description of the controls follows.

1. **Time-Varied Gain (TVG).** TVG, a function of the signal amplifier PCB, increases the gain of the amplifier so that it receives the weaker signals from the deep sediments within the bottom. The gain increases as the point of electric contact sweeps from the center toward the end of the drum.

The "initial" control establishes the level of gain from which the gain will increase. The slope control establishes the rate at which the gain increases (i.e., slope of the gain curve). Figure 9 illustrates the concept of TVG.

The initial gain affects the one-third of the record at the beginning of the sweep, the slope controls the middle one-third of the record, and the overall gain affects the outer one-third. These controls are all interrelated so that a balance must be met by adjusting all three controls.

2. **Overall Gain.** The overall gain (Fig. 8) controls the gain of the entire record. The TVG is superimposed on top of the overall gain over the inner two-thirds of the record.

(d) **Output Power Level.** The power level switch controls the amount of energy put into the water by the pinger probe. The switches add either 0.12 joules or 0.25 joules to the output. Since the instrument is a one-half joule system, there is always at least a 0.12-joule output. The effect of the switches is shown in Table I.

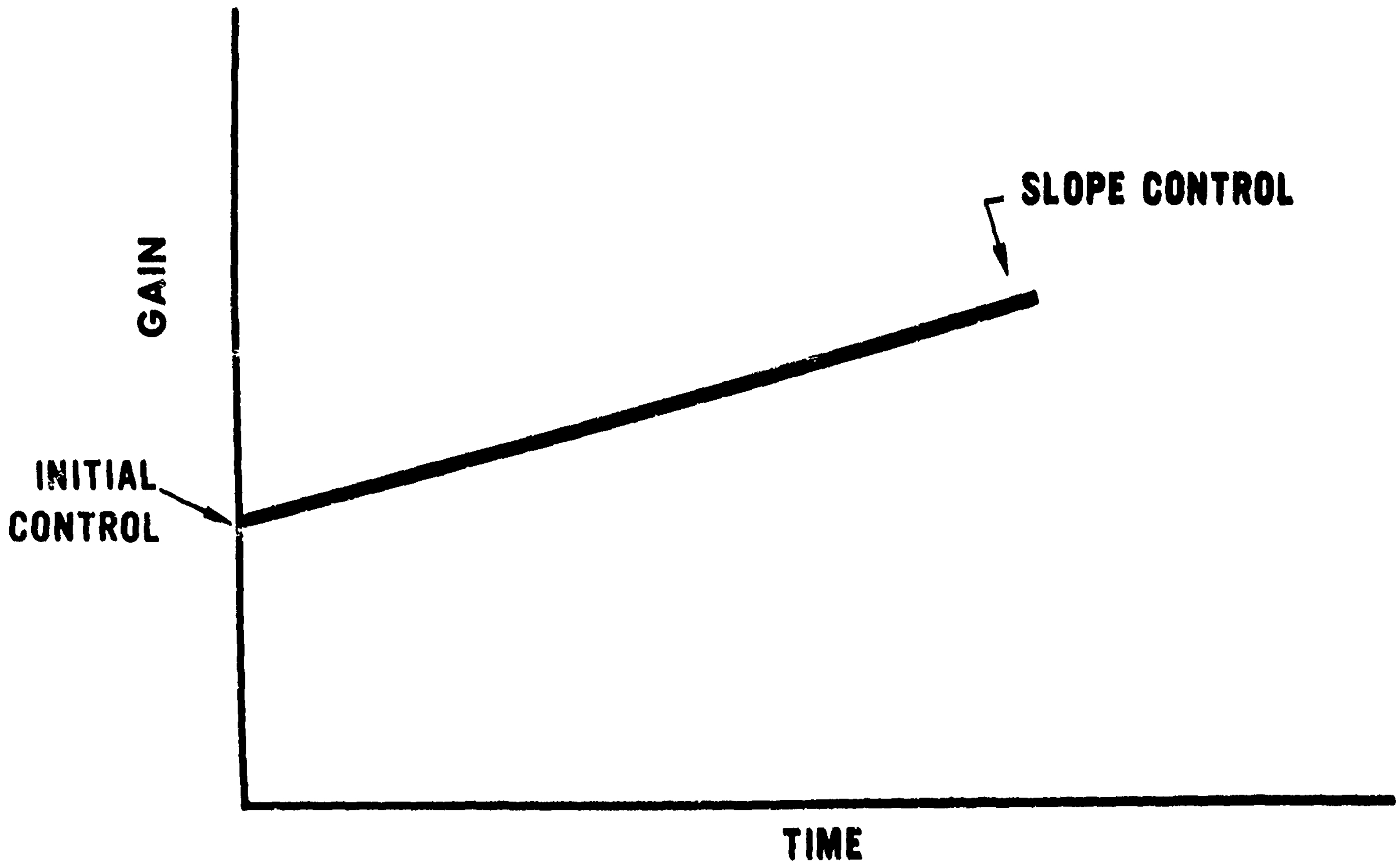


Fig. 9. Time varied gain curve.

Table I. Power Output

.12J SWITCH ON	.25J SWITCH ON	% MAX. POWER OUTPUT
X	X	100%
	X	75%
X		50%
		25%

(e) **Range Scale Switch.** The range of the instrument is most easily defined as the width the channel represents. AUSE has full-range scales of 150, 300, and 600 feet. That is, on the 150-foot range, the farthest point that will be seen on the side scan sonar record is at a radial distance of 150 feet from the fish. The 600-foot scale will insonify four times as much ocean floor as the 150-foot scale, but the image of a target will be one-fourth the size.

Since the range scale is determined by the helix drum speed and is therefore the same for both channels, the side scan sonar and the sub-bottom profiler are on the same range scale.

The 600-foot range scale is useful only for performing a side scan search over a large area for a large target. The necessary detail cannot be seen on the sub-bottom profiler record on the 600-foot scale.

(5) **Printed Circuit Boards.** The electronic components are organized on Printed Circuit Boards (PCB) according to function and are accessible through the two covers on the front panel (Fig. 7).

The PCBs are identified in three ways:

(a) **Color Code.** The tabs on the top edge are colored and match the color and name on the underside of the cover.

(b) **Name.** The name describing the function of each PCB is printed on it.

(c) **Pin Code.** The pin arrangements on each PCB match the receptacle in the recorder into which the PCB fits. The pins on all PCBs are different so that a PCB will not fit into the wrong receptacle. The sonar amplifiers and printed amplifiers for both channels are identical and can be interchanged.

The instrument is accompanied by two sets of spare PCBs (one set for each channel) to facilitate repairs in the field. The power switch must be in the "off" position when changing PCBs since some have points of high voltage.

After a PCB is replaced, the covers should be replaced to prevent foreign matter, water, or tools from entering the recorder. Screw drivers left on the front panel can fall into the PCB compartment and short out the circuit.

(6) **Event Marker.** The event marker prints a dark line continuously across the record. These marks can be numbered and used during a survey to correlate the record with the navigational plot.

(7) **Lamp Intensity Control.** The lamp intensity knob controls the intensity of the two lights that illuminate the controls and the four lights over the record (Fig. 9). Lights were added to this model to permit night operation.

(8) **Elapsed Time Meter.** The elapsed time meter (Fig. 9) records the number of hours (and tenths of hours) that the instrument is in use. It was added to establish the mean time between failure of components and to assist in determining the expected life of wearing parts such as helix heads and strips. Reliability discussions during the contract negotiations emphasized the difficulty of testing the instrument for reliability. It was decided that the most equitable and economic arrangement would be for the contractor to replace components that fail within a specific time span.

The elapsed time meter is connected to the helix drum motor circuit so that it is operating whenever the instrument is operating.

(9) **Built-In Tests (Input).** An oscillator built into the instrument produces a signal of predetermined frequency and amplitude. The signal is applied to the amplifier by pushing the "Test" switches on the front panel. If the amplifiers

are putting out a signal at a designated level, a light line will appear on the record. If the amplifier is too weak, no line will appear.

The tranducers need not be connected to the recorder.

(10) **Built-In Tests (Output).** This test determines whether or not the transducers are transmitting. A test hydrophone (Fig. 10), connected to the recorder in place of the operational hydrophone, is held 5 feet from the pinger probe, or 7 feet from the side scan "fish" (Fig. 11). When the output test switch is pushed, a line will appear between the center of the record and the first scale line, indicating that the transducers are transmitting properly.

The output built-in tests must be performed out of the water.

(11) **Fuses.** The fuses are located on the first panel under the threaded (Fig. 8) caps.

In the prototype instrument, the fuses were located inside the recorder case near the rear. To replace a fuse, it was necessary to remove the recorder from its case and turn it on edge. Placing the fuses on the front panel is an obvious advantage.

(12) **Case.** When all doors on the front panel are closed, the recorder case is splash-proof. It can be operated with the cover on and the record being observed through the window, or in less severe conditions, the cover can be removed.

Three ventilators are provided in the case:

(a) **Front.** A fan is mounted behind the filter shown in Fig. 6. It draws cool air into the case to cool the electronic components. The filter traps airborne particles and water and prevents them from entering the case. A metal louver (not shown) is placed over the filter to protect it. The fan is wired into the power switch and operates whenever the recorder is operating.

(b) **Side.** The side vent arrangement is identical to that of the front with the exclusion of the fan. Air drawn in by the fan is exhausted through the side and bottom vents.

(c) **Bottom.** The bottom of the case has a hole approximately 2 inches in diameter. A large baffle on the inside prevents direct entrance of water.

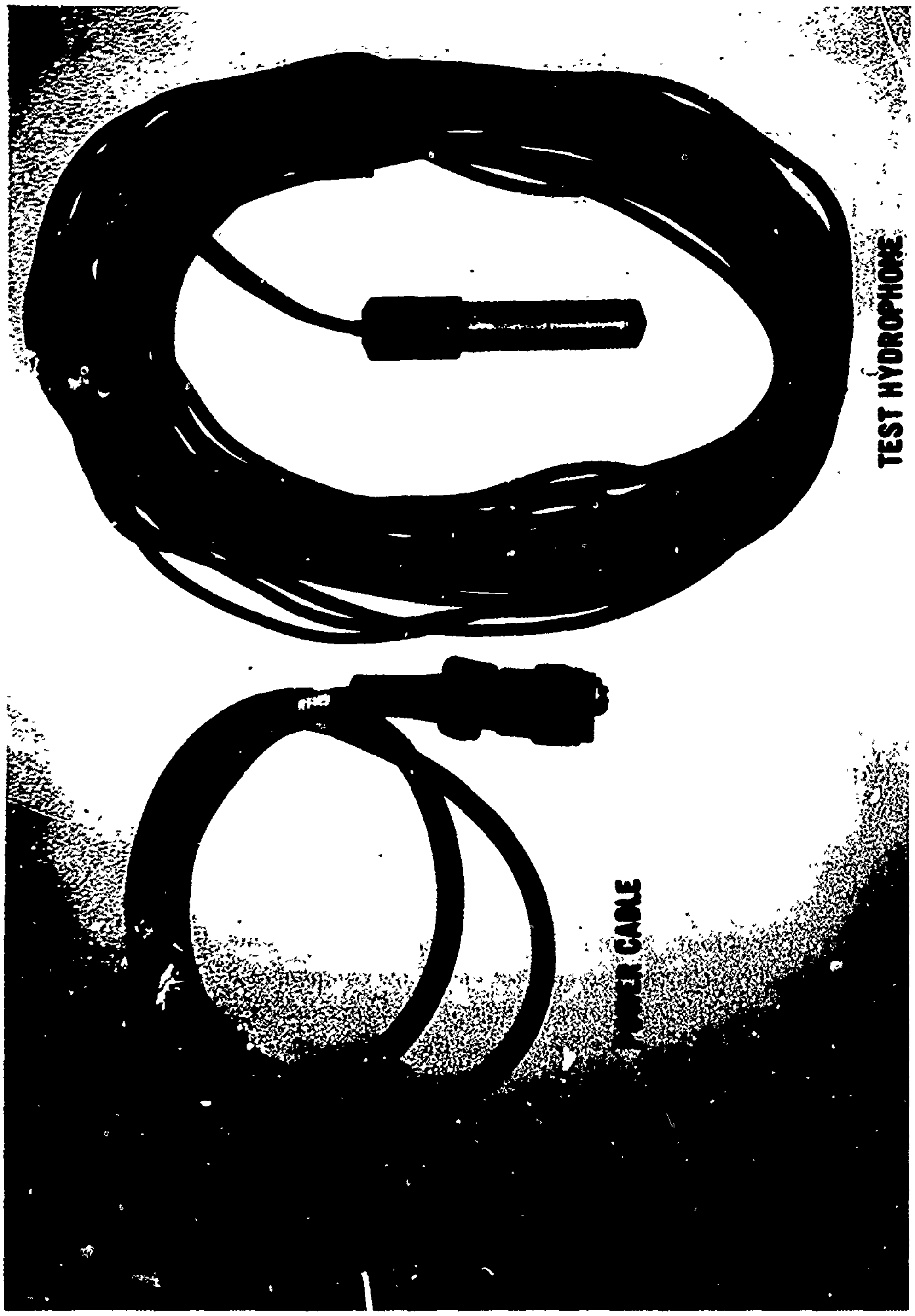


Fig. 10. Test hydrophone and recorder power cable.

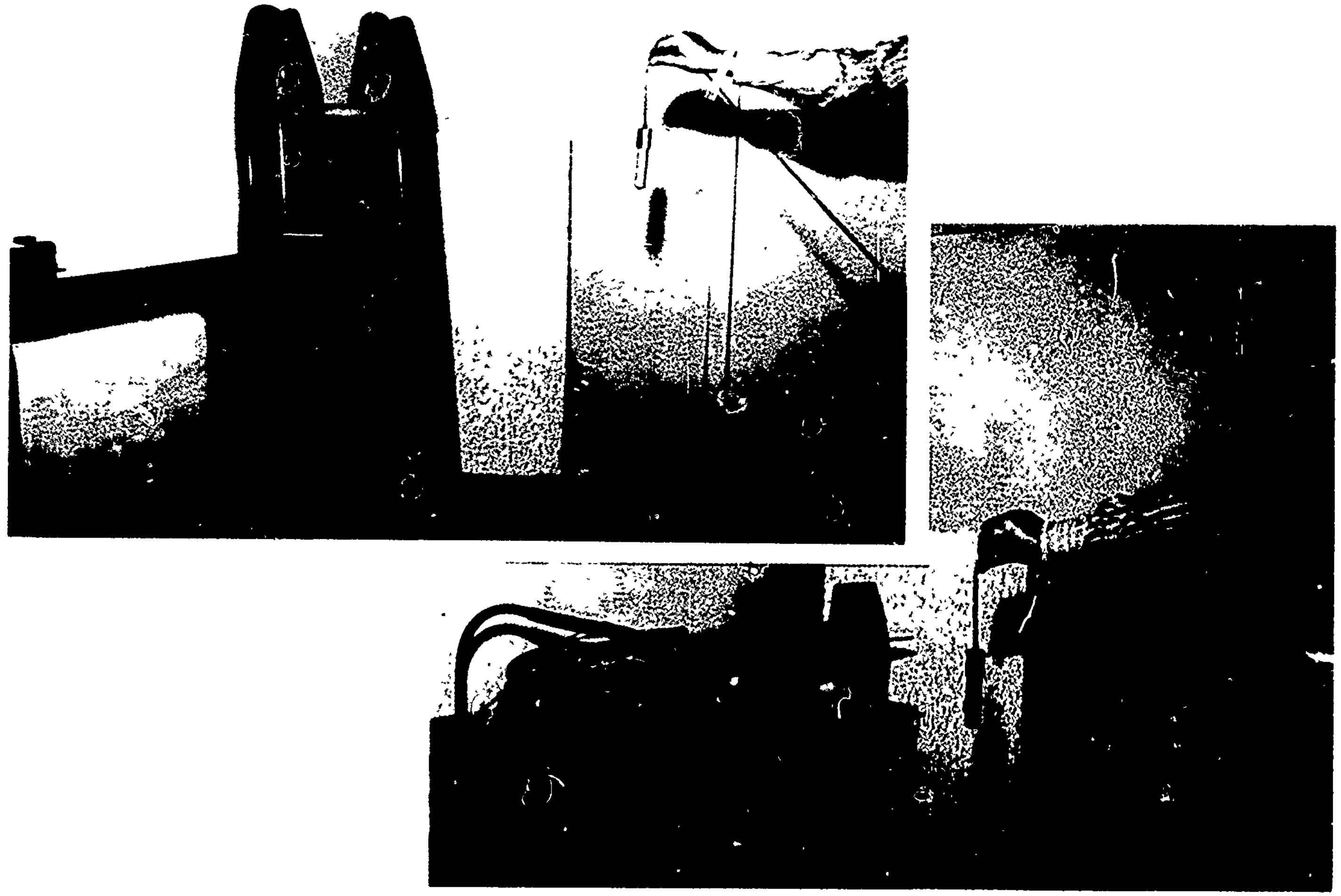


Fig. 11. Test hydrophone use.

As the recording paper passes between the helix blade and strip, a small amount of paper is scraped off the back. This fine powder falls to the bottom of the case and is blown out through the bottom vent.

The two handles on the front panel should not be used to lift the recorder. They are provided to facilitate the removal of the recorder chassis from the case.

Two straps are provided to assist in the removal of the recorder from the storage chest.

(13) Recorder Specifications.

Size	24 in. x 31.5 in. x 12 in.
Weight	107 lb
Range Scales	150, 300, 600 ft
Scale Lines	25 ft
Voltage	24 volts DC
Current	7 amps max.

b. **Pinger Probe.** The function of the pinger probe (the sound source for the sub-bottom profiler) is to transmit a 5-kHz acoustic pulse of 0.4-millisecond duration into the sub-bottom sediment layers. The transducer assembly supported between two fiberglass foam-filled floats (Fig. 4), consists of three truncated conical crystal transducers in a line array. The face of the transducers is protected by a rubber pad approximately 1 inch thick. A 70-foot, 5/8-inch-diameter combination electrical and tow cable is used to tow the pinger probe. The connection of the tow cable to the pinger probe is approximately 10 inches to the rear of the nose on the outside of the float (Fig. 4). Towing from this position, the transducer will plane away from the boat and avoid the wake. The turbulence of the wake attenuates the outgoing signal.

A kellum grip secures the cable to the float to relieve the tension on the electrical connectors at the transducer.

The specifications are as follows:

Size	62 in. x 28 in. x 14 in.
Weight	92 lb
Frequency	5 kHz
Pulse Duration	0.4 millisecond
Beam Pattern	30° x 120° elliptical cone

c. **Hydrophone.** The function of the sub-bottom profiler hydrophone is to receive the acoustic reflections from the bottom and sub-bottom layers, transduce them to electrical signals, amplify these electrical signals, and deliver them to the recorder for further processing and display.

The hydrophone consists of an oil-filled hose containing an eight-element array of ceramic, acceleration-cancelling crystal transducers and a preamplifier. A 70-foot electrical cable is used to tow the hydrophone and connect it to the recorder.

A 30-foot tail of ¼-inch cord is attached to the end of the hydrophone and enhances the hydrodynamic characteristics of the hydrophone. Loose knots can be tied in the tail to increase the drag of the tail. The tail will also help straighten the hydrophone and take out the slight curve that is caused by coiling it into a storage chest.

The drag created by the tail lifts the hydrophone and assists in counteracting the sinking force of the electrical cable. This is important when operating at slow speeds with the hydrophone a great distance behind the vessel.

An eight-element hydrophone receives only that signal which approaches it perpendicular to the long axis of the array. Signals received parallel to the axis are rejected. The hydrophone is neutrally buoyant. However, the weight of the tow cable causes it to sink when placed in the water.

The specifications are as follows:

Size	15 ft long x 1 in. dia.
Tail	30 ft long x ¼ in.
Tow Cable	70 ft long x ½ in. dia.
Weight	25 lb
Bandwidth	450 Hz to 5 kHz
Number of Elements	Eight

d. Side Scan Sonar. The side scan sonar transducer (Fig. 4), called the fish, has 16-inch long rectangular transmit-and-receive transducers mounted behind blue polyurethane windows.

The beam is approximately 2° by 40° (horizontal and vertical width respectively) and is tilted down 10°. The transmitting pulse has a frequency of 105 kHz ± 10 kHz, with a duration of 0.10 millisecond.

No circuitry is enclosed within the towed fish. With the exception of the nose section, the body of the fish floods when submerged. The nose section is weighted sufficiently to cause the fish to maintain the proper attitude when under tow.

The tail section is fastened to the body by shear screws. If the fish becomes entangled in an obstruction, the tail will break loose, allowing the fish to free itself. The tail section, connected to the fish by a cord, is recovered with the fish and remounted.

When the tail section separates from the body, the fish will become very unstable and the quality of the record will deteriorate.

The specifications are as follows:

Length	52 in.
Diameter	4 in.
Fins	12 in.
Weight	Approximately 40 lb

e. **Depressors.** A depressor is a hydrodynamic body that exerts a downward force at a specified speed several times its weight (Fig. 4). They are utilized with the side scan sonar fish in deep water to hold the fish down. They increase the depth that the fish can reach with a limited amount of cable. The effects of the depressor are discussed in paragraph G.

f. **Test Hydrophone.** The test hydrophone (Fig. 10) is used with the built-in test capability of the recorder to test the pinger probe and side scan sonar transducers to determine whether or not they are transmitting at a prescribed level (Fig. 11).

The test hydrophone can also be used to determine the water depth if the sub-bottom profiler hydrophone is inoperable. It can either be tied to the profiler hydrphone or hung over the side of the boat. The bottom will appear on the record, but no penetration will be achieved.

g. **Replacement Parts Boxes.** The replacement PCB, helix strips and blades, light bulbs, and other spare parts are stored in two metal chests (Fig. 4). They are taken on the boat during a survey so that repairs and maintenance can be accomplished on the vessel.

D. Deployment

1. Side Scan Sonar—General Techniques.

a. **Towing Arrangements.** In deploying the side scan sonar fish, care must be taken to keep it out of the wake and propeller noise and turbulence because they cause a clouding of the record.

(1) **Shallow Water.** The fish should be towed from the bow of the boat so that it will be positioned in front of and below the propeller wash and out of the wake. Records taken in shallow water frequently pick up some noise from the boat. This is not usually serious and, in some cases, may supply additional information (see paragraph F).

(2) **Deep Water.** The fish may be towed from the stern or side, since it will be sufficiently deep and surface noise will not be recorded.

b. **Launching.** The fish should be dropped into the water as shown in Fig. 12. Sufficient cable should be left free to allow the fish to sink below the boat; then the remaining cable is paid out hand-over-hand. If the fish is launched with some slack line rather than being lowered over the side, it will not strike the side of the vessel as it pitches and rolls in choppy seas.

c. **Cable Length.** For optimum results, the fish should be at a height above the bottom equal to 20 percent of the full-range scale. The best way to determine this is by reading the height of the fish above the bottom from the record (paragraph F) and adjusting the cable length accordingly.

The initial cable length should be approximately twice the desired depth of the fish when under way. When this length exceeds the depth of water, the procedures outlined in the following sections must be followed or the fish will strike the ocean bottom.

d. **Vessel Maneuvers.**

(1) **Getting Underway.** When the initial cable length exceeds the water depth, the fish should be launched as described above. As the cable is paid out, the vessel should get underway slowly, and the AUSE operator should watch the record to insure that the fish does not come too close to the bottom. The speed should be increased gradually until the cable is out.

Fig. 12. Launching the side scan sonar.

If deeper water is nearby, the fish should be deployed in deep water and moved into the survey area at cruising speed.

(2) **Turns.** When the vessel turns, the fish has a tendency to move toward the inside of the curve. Since it does not travel as far as the vessel per unit time, the fish's speed decreases, and it sinks somewhat. If the fish is towed from the bow or side of a large vessel, it may be in the vicinity of the propeller. Therefore:

(a) Turns should be made toward the side that the fish is on to avoid drawing the fish or tow cable into the screw.

(b) Turns should be gradual.

(c) If sharp turns are made, the fish should be pulled up to compensate for its sinking.

When the fish is towed from the bow of a small boat with a short cable, the above factors are not as critical because the fish is under the bow and stays there during turns.

(3) **Stopping.** If the cable length is greater than the water depth:

(a) The vessel should be slowed and some cable pulled in while the AUSE operator watches the record to insure that the fish will not sink and strike the bottom. When it is evident that the cable length is less than the water depth, the vessel may be stopped and the remaining cable retrieved.

(b) If deep water is nearby, the vessel should be moved to that area and stopped while the fish is retrieved.

Before the fish is pulled into a small boat, the water inside must be drained over the side.

e. **Deep Water Deployment.** Depressors are provided to hold the fish down in deep water to obtain adequate coverage with a limited length of cable. The use and deployment of the fish with the depressor follows:

(1) **Tie Points.** One Kellum grip is moved to the mid-point of the cable and the other to a point within 3 to 5 feet of the fish. A light line approximately 20 feet long is used to tie a depressor to the Kellum grip at the midpoint. The second depressor is tied to the Kellum grip near the fish with a line approximately

10 feet long. The line should be of sufficient length to allow the depressor to hang below the sonar fish. If the line is weaker than the sonar tow cable and the depressor becomes lodged in an obstruction, the line will fail, allowing the fish to rise and avoid similar obstacles.

(2) **Launching.** Launching the fish with depressors requires close coordination between the boat operator and AUSE operators. Launching with cable lengths greater than the water depth requires particular attention. This operation requires one boat operator, one AUSE operator watching the recorder, and one or two AUSE operators handling the fish and depressor. The following procedure will assist in the successful launch of the fish with depressors.

(a) The Kellum grip should be tied off at the top end of the cable to a cleat. For safety purposes, the cable should be wrapped around a cleat or capstan or tied off again with a line.

(b) The depressor is lowered over the side and the sonar fish launched as described above. Cable is paid out hand-over-hand until the fish is within 25 to 35 feet of the bottom. The AUSE operator at the recorder can make this determination.

(c) When the fish appears to be within 25 to 35 feet from the bottom, the vessel should be moved ahead slowly. The record will show that the fish is rising somewhat (i.e., the bottom appears to drop off). More cable can be paid out and the speed gradually increased. As the speed increases, the tension in the cable will increase due to the effect of the depressor. If the speed is increased too fast, the tension in the cable will be too great and the cable will be pulled from the grasp of the men handling it.

If the fish is not within 20 to 30 percent of the full range scale from the bottom, the vessel speed should be reduced until the desired depth is obtained.

(3) **Recovery.** Recovering the fish with a depressor requires close coordination among the crew members. If the boat slows too much, the depressor or sonar fish will strike the ocean bottom. If the vessel does not slow down enough, the depressor will still be exerting a downward force and it will be almost impossible to retrieve the fish. If deeper water is not nearby, and the procedure for recovery outlined in the previous section cannot be used, the following procedure can be used:

(a) The vessel should be slowed gradually to reduce the tension on the cable.

(b) The fish should be retrieved while the recorder is watched to insure that the fish stays above the bottom. When it is apparent that the cable length is less than the water depth, the vessel should be stopped and the remaining cable retrieved.

2. **Sub-Bottom Profiler.**

a. **Towing Arrangement—Hydrophone.** The hydrophone should be towed in a location that is free of turbulence and noise. Off the stern and outside the wake is usually the best arrangement.

The hydrophone should be approximately 3 to 4 inches under the surface; that distance is one-quarter of the wavelength of the 5-kHz pulse. If two returning pulses arrive at the hydrophone at the same time, one directly from the ocean bottom and the other reflected off the water surface, the net effect will be additive if the hydrophone depth is 3 to 4 inches under the surface. If the hydrophone is allowed to sink much below the designated depth, the two pulses will arrive out of phase and the result will be subtractive.

In addition to the apparent lack of penetration caused by a low hydrophone, a second image of the ocean bottom will appear slightly offset from the original image.

The depth of the hydrophone is controlled by the vessel speed and the length of tow cable out.

b. **Tow Arrangement—Pinger Probe.** The pinger probe should be towed in a position free of turbulent water. The transducer faces must remain submerged at all times. If air is allowed to pass under the transducer or the pinger probe is pulled out of the water in rough conditions, the signal will be attenuated and none will reach the ocean floor. The result will be a series of white lines across the entire width of the sub-bottom profiler channel. Reducing the vessel's speed will keep the pinger probe from being pulled out of the water at the top of each wave. The pinger probe can be towed inside the vessel's wake if the wake is sufficiently flat.

c. **Relative Position of Hydrophone and Pinger Probe.** In all cases, the hydrophone and pinger probe must be positioned side by side. As described above, the hydrophone rejects axial acoustic energy and the pinger probe has an asymmetric lobe ($30° \times 120°$); therefore, the two transducers must be positioned as shown in Fig. 13.

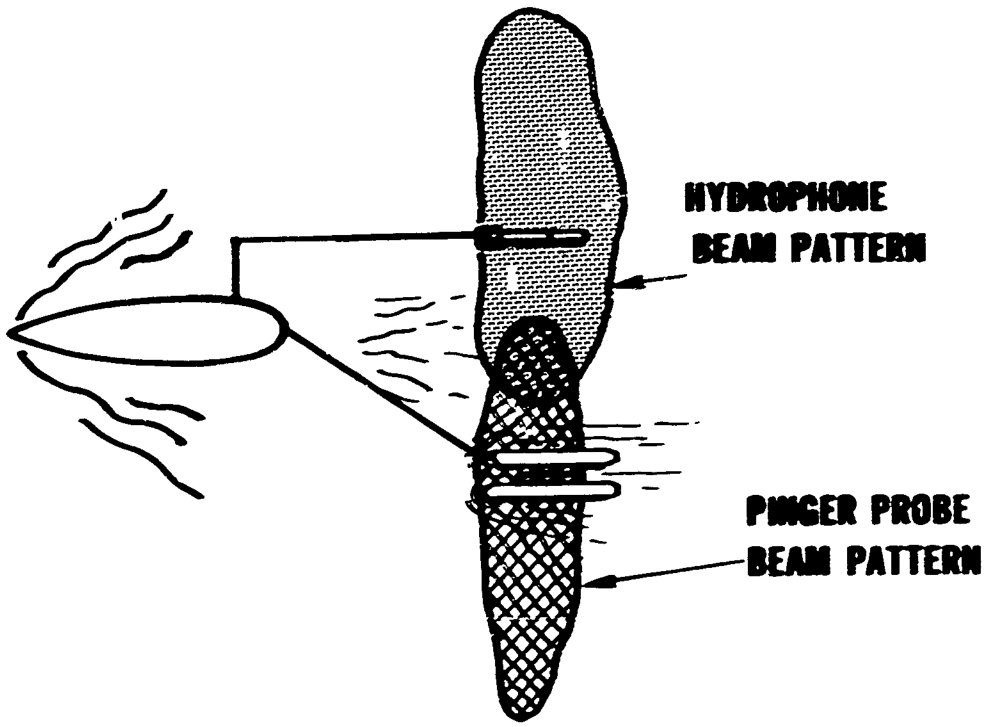


Fig. 13. Hydrophone and pinger probe position.

If the separation between the pinger probe and hydrophone exceeds the water depth, the penetration will fade because less acoustic energy arrives at the hydrophone. In shallow water, the transducers should be towed close to the stern to reduce the separation between the hydrophone and pinger probe.

Where possible, the pinger probe and hydrophone should be positioned on opposite sides of the wake. This practice will break up multiples and direct returns (paragraph G) by attenuating the acoustic energy in the turbulence of the wake.

In shallow water, the pinger probe should be pulled closer to the stern to reduce the separation.

d. **Deployment Configurations for Vessels of Various Sizes.** The deployment configuration of the sub-bottom profiler can be modified to accommodate various sizes of vessels. The optimum arrangement is a combination of many factors, as shown in Fig. 14. The following discussion outlines the rationale behind the configurations.

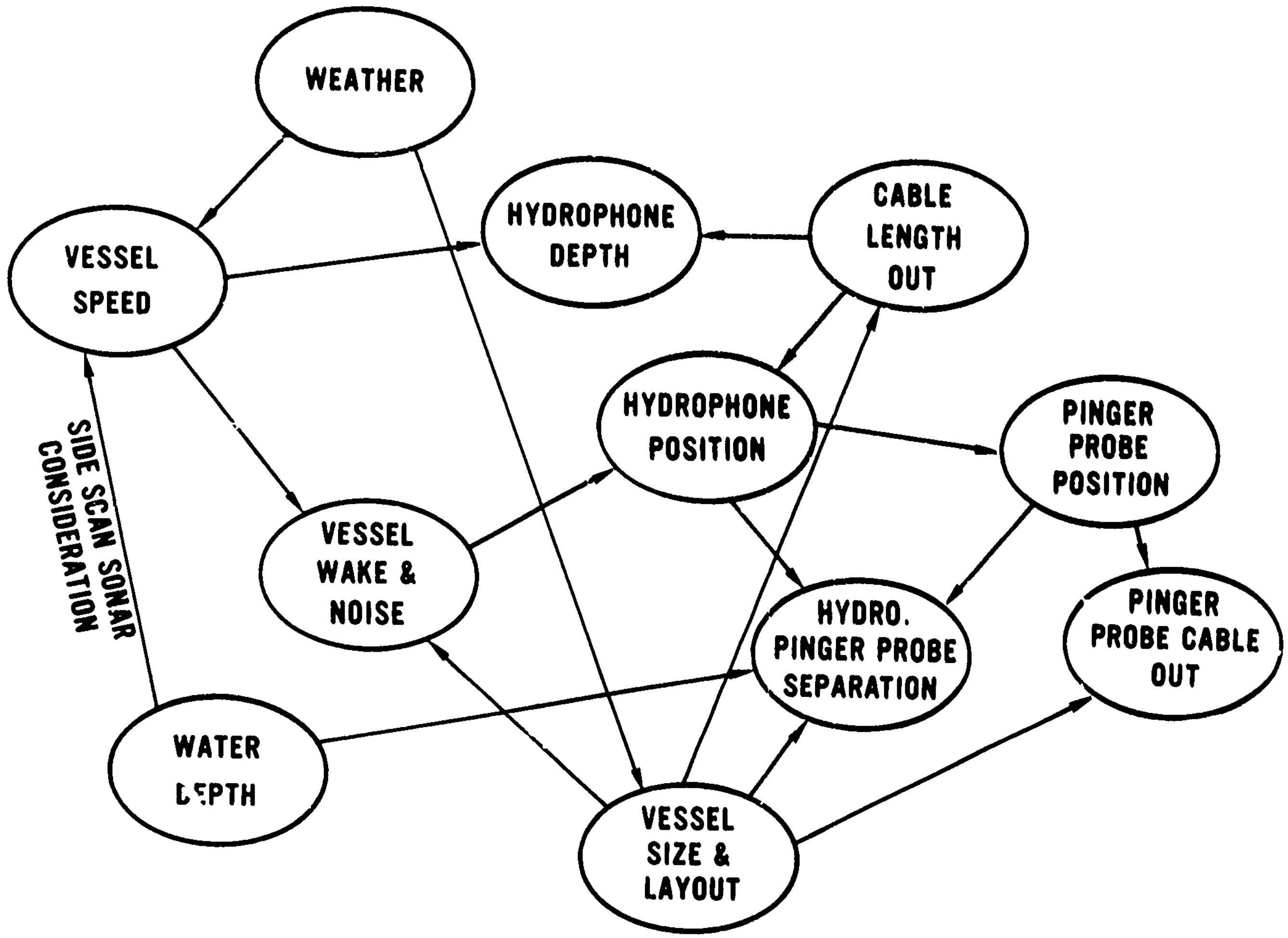


Fig. 14. Interrelation of deployment—configuration factors.

(1) **30-Foot Boats or Less.** The pinger probe and hydrophone should be positioned on opposite sides of the wake (Fig. 15).

(2) **30- to 70-Foot Vessels.** The two transducers should probably be towed on one side of the vessel (Fig. 15). If the wake is sufficiently smooth, the pinger probe may be towed behind the vessel.

(3) **100-Foot Ships.** The pinger probe and hydrophone should usually be towed on the same side of the vessel and forward of the stern to avoid the wake. For navigational coordination, it is advisable to place the recorder in the wheelhouse. The limited length of cable available to reach the wheelhouse necessitates towing the transducer alongside the vessel (Fig. 15).

e. **Deployment of the Sub-Bottom Profiler.** The following procedure should be followed to deploy the sub-bottom profiler:

(1) The tow cable is tied off at the appropriate length and the pinger probe is placed over the side of the vessel (Fig. 16). Care must be taken not to pull the cable between the transducers and the Kellum grip. As the vessel moves off slowly, the cable is paid out hand-over-hand. The vessel must be moved slowly to keep the pinger probe well aft and the cable out from under the vessel.

(2) The hydrophone is paid out hand-over-hand, starting with the tail. The tail or any other part of the hydrophone must not be thrown into the water. It will tangle.

f. **Retrieval of the Sub-Bottom Profiler.**

(1) As the vessel comes to a gradual stop, the pinger probe is pulled in and lifted over the side. Care must be taken to protect the transducers and the cable connections on top of the transducers.

(2) The hydrophone can be retrieved last because it will hang straight down and presents no hazard to the vessel's propeller or rudde . The hydrophone is neutrally buoyant but sinks under the weight of the cable.

3. **AUSE Deployment Sequence.**

a. The recorder is mounted in the rack in the MSB shelter cabin and the power cable connected to the batteries (Fig. 17).

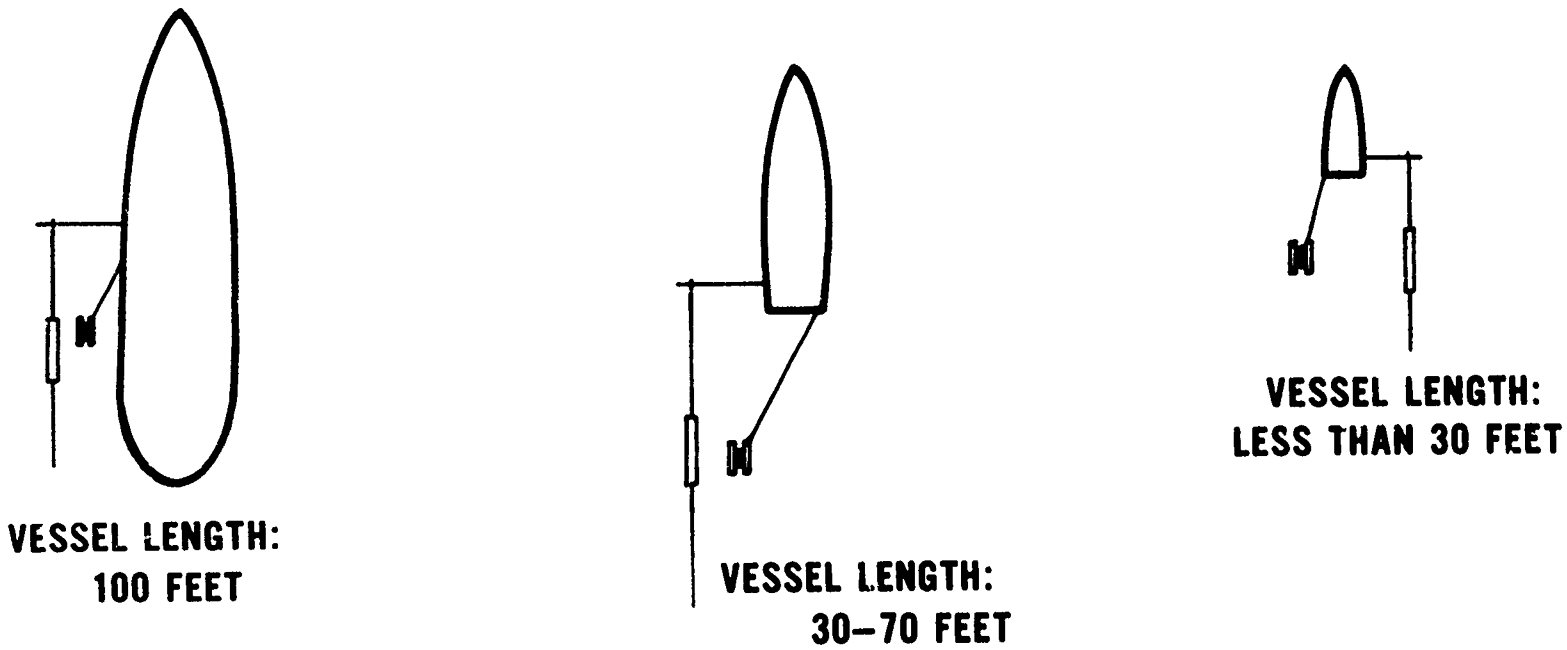
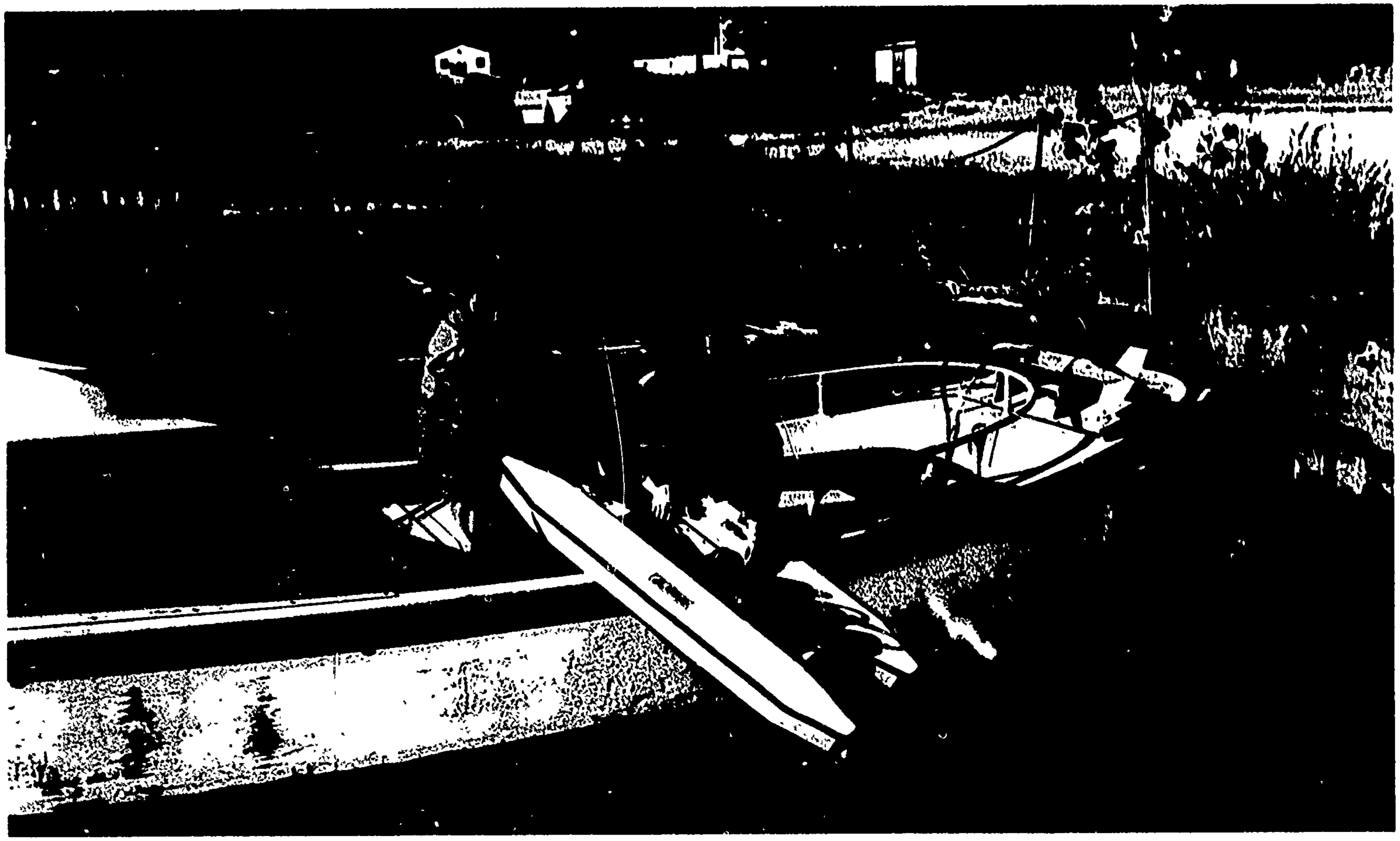
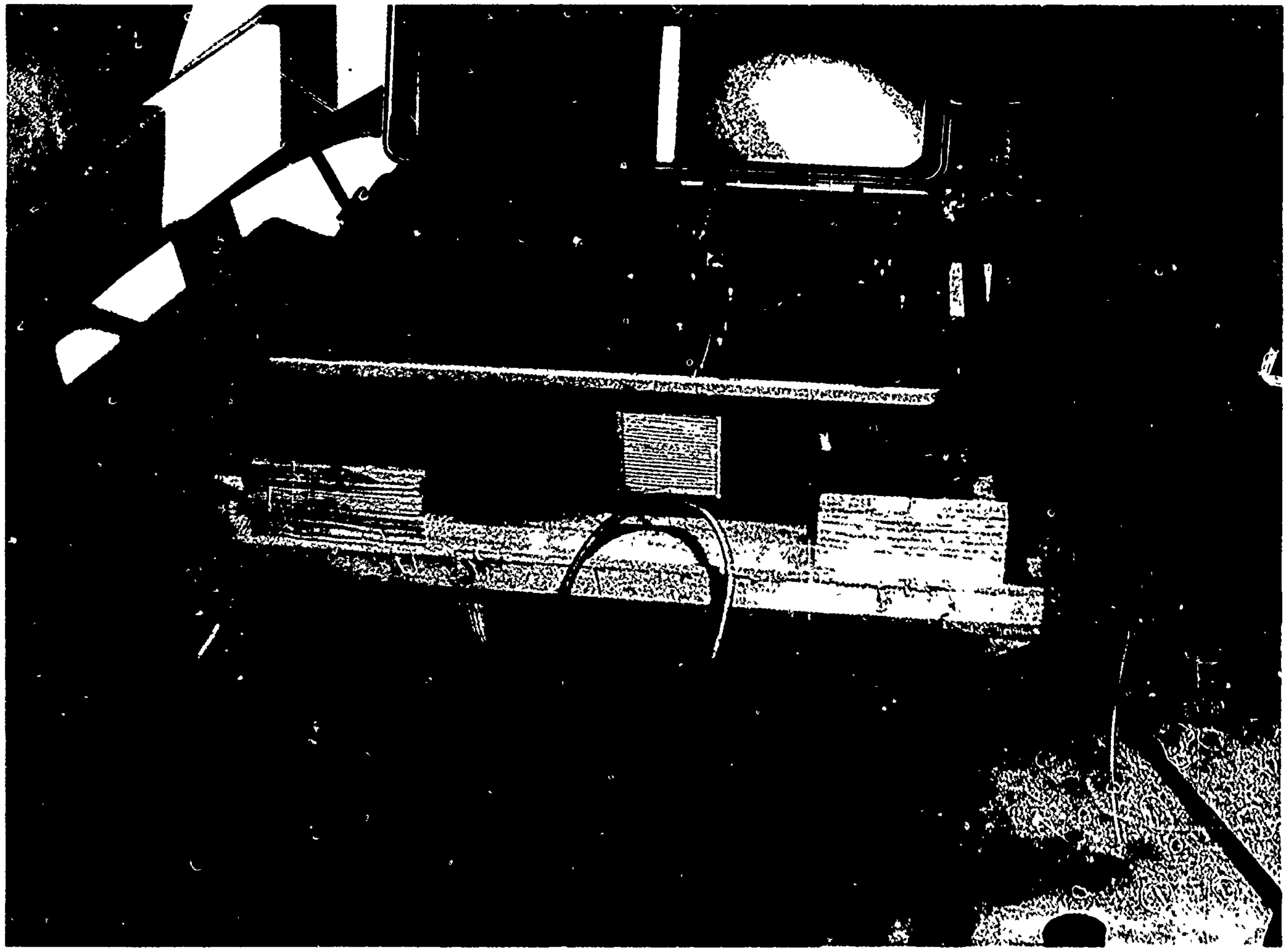


Fig. 15. Deployment configuration from various vessels.



T14469

Fig. 16. Deployment of the pinger probe.



T11689

Fig. 17. Oceanographic records mounted in surf boat.

b. The side scan sonar rack is mounted on the stern and tied to the cleats and the fish is placed in the rack and secured (Fig. 18).

c. The hydrophone boom is mounted on the starboard rail (Fig. 19) and the hydrophone and cable fed through the eye in the end. The boom swings toward the tow and rests on the gunwales when not in use. The fixture is designed so that the force of the hydrophone under tow holds the boom out to the side.

d. The pinger probe is placed in the stern on the floor.

e. The cables are connected to the recorder.

f. Upon arrival at the survey site, the pinger probe is placed into the water and 25 to 30 feet is paid out as the vessel moves off.

g. The hydrophone is fed into the water tail first. When all the cable is out, the boom is swung out to the side.

h. The side scan sonar fish is tied off (Fig. 20) and launched (Fig. 12). Deep water deployment procedures may be necessary.

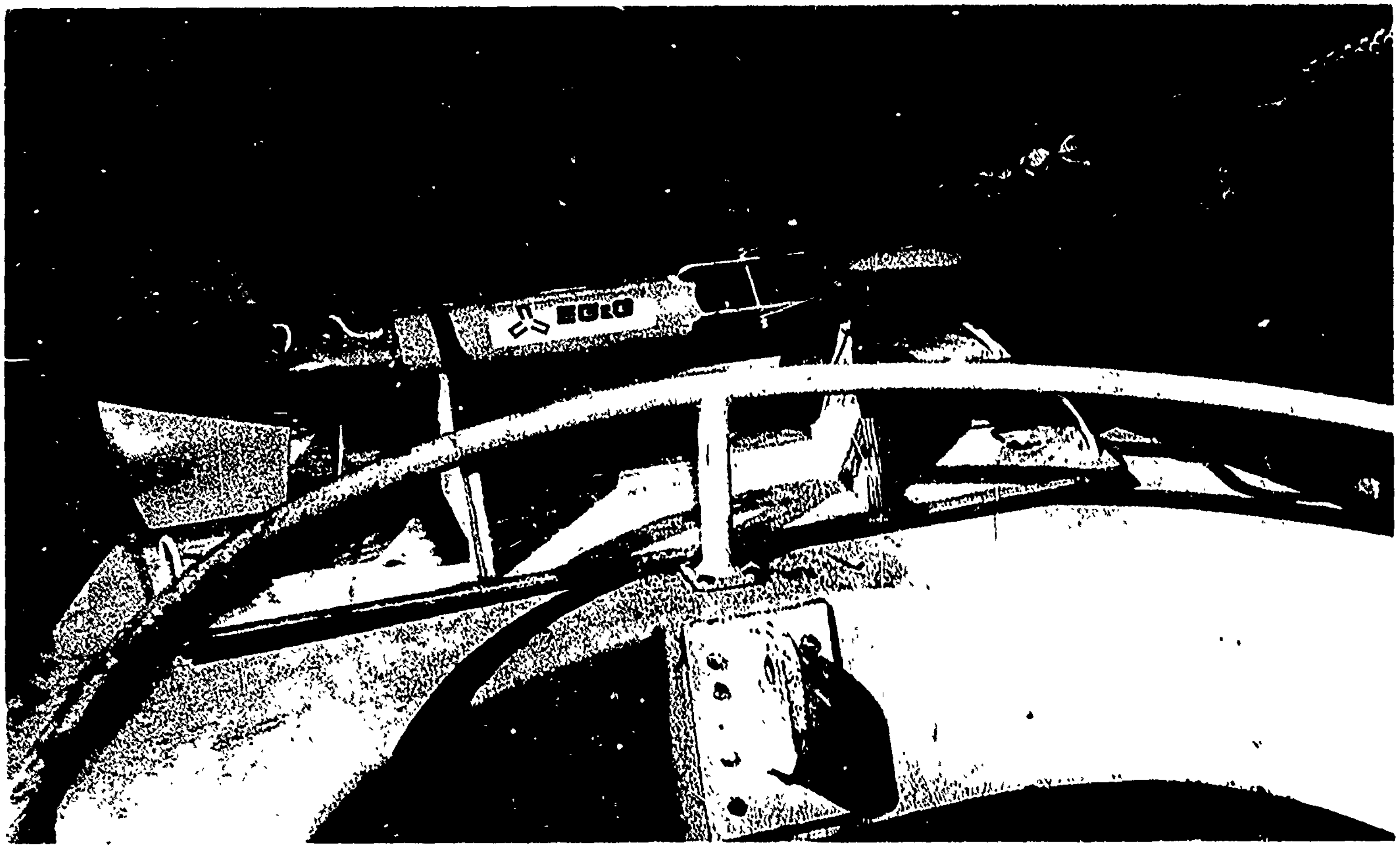
i. In fairly calm conditions a speed of 6 knots yields good records.

4. AUSE Recovery Sequence.

a. If the side scan sonar cable length is greater than the water depth, the fish is retrieved as the MSB slows as described above. The fish is placed in the rack on the stern.

b. The pinger probe is pulling in while the boat is moving ahead slowly or stopped with the bow into the weather.

c. The hydrophone boom is swung in and the hydrophone lifted out of the water.



T11696

Fig. 18. Side scan sonar rack.

T11693

Fig. 19. Hydrophone boom fixture.

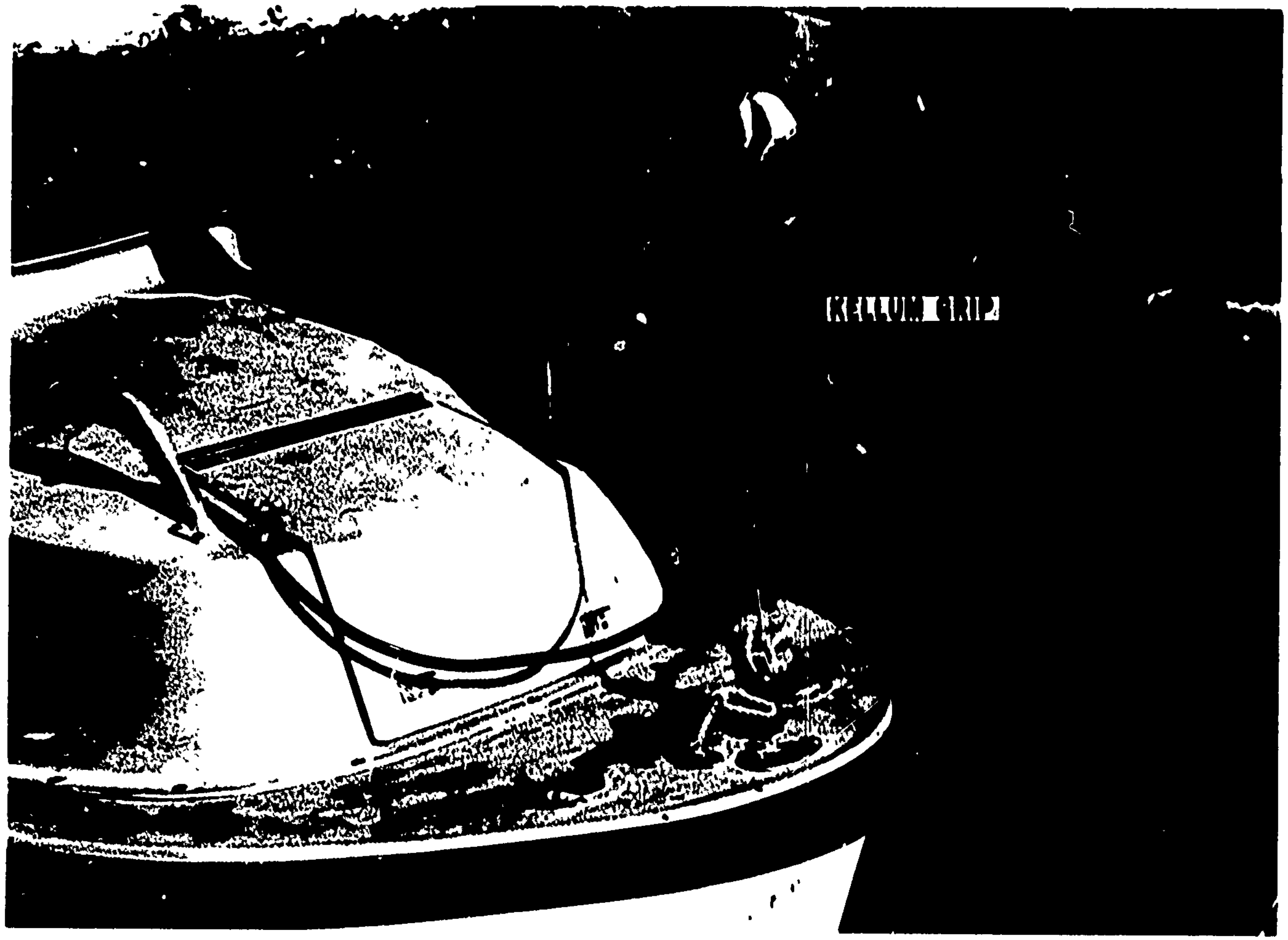


Fig. 20. Side scan sonar tie down.

E. Operation and Maintenance

1. Operation.

a. Placing Recorder in Operation.

(1) After the recorder is placed in the MSB and the power cable is connected to the batteries, the lid is lifted and propped up with the leg.

(2) A roll of paper is placed in the paper compartment so that the paper feeds off the top of the roll. The end of the paper is drawn out of the compartment and slipped through the slot leading to the paper take-up compartment (Fig. 21).

(3) The reel is taken from the take-up compartment and the right end removed.

(4) The paper is placed into the slot on the reel. The end of the reel is replaced and the reel twisted three or four times to roll enough paper on to insure that the paper will stay.

(5) The left end of the reel is placed into the slot in the paper take-up compartment and the right end pressed into the corresponding bracket.

(6) The power switch is turned on and the paper take-up reel allowed to take the slack out of the paper. The power switch is turned off.

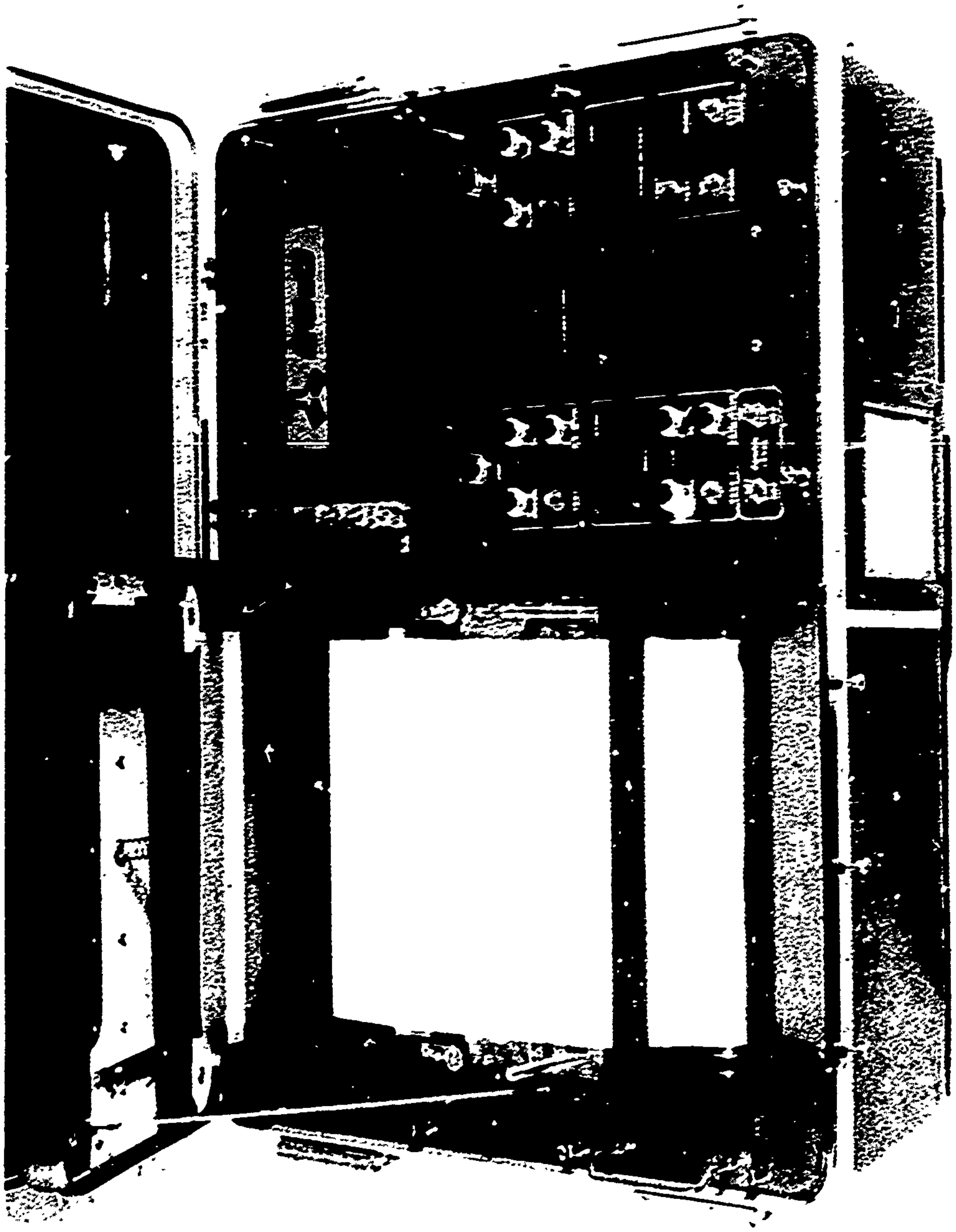
(7) The thumb screws are turned to maximum height and the lid closed and tightened.

(8) The writing mechanism is adjusted by turning on the recorder and depressing and holding the Event mark. A dark line should appear across both channels. If it does not, the window in the lid is opened and the thumbwheel turned until the dark line appears across the record. Lowering the helix blade more than is necessary to cause even printing may cause excessive wear of the helix strips and blades.

(9) The transducers are deployed and the instrument tuned.

b. Tuning. To tune either the side scan sonar or sub-bottom profiler:

(1) The initial gain is increased until the bottom appears on the record.



T11023

Fig. 21. Paper feed arrangement.

(2) The slope is increased to bring in the middle of the record.

(3) The manual gain is increased to bring in the outer edge of the record.

Since all controls are interrelated, it is necessary to go through the procedure again and readjust the gains until a balance is reached and the record is of uniform intensity. Generally, the second adjustment will require decreasing the initial gain and increasing the overall gain slightly.

When searching an area for large objects with relief above the bottom, (e.g., sunken vessels or rock outcroppings), the side scan sonar gain should be at such a level that the acoustic shadow is distinct, but not so high that the detail is obscured.

The sub-bottom profiler gain must be high enough to receive returns from all the layers within the sub-bottom. Excessive gain will darken the record and obscure the sub-bottom layer acoustic signature.

Sediment characteristics change and may require frequent minor adjustments of gain to give the best results.

c. Power Level Setting. Transmitting power depends on sediment characteristics and operating conditions.

(1) Shallow Water. In water depths up to 50 feet, both power level switches (Fig. 9) should be in the OFF position. As the depth approaches approximately 90 feet, some combination of the switches will probably give the best results (Table I).

(2) Deep Water. In water in excess of 90 feet, both switches should be in the ON position. This will give the maximum power output (½ joule) and compensate for attenuation and spreading losses.

d. Transducer Configuration Adjustments. The following record phenomena may be caused by the transducer towing arrangement. They may be abated or eliminated by executing the recommended adjustments.

Record	Causes and Adjustment
Double bottom	Hydrophone too deep; vessel speed should be increased or hydrophone tow cable length decreased.

Record	Causes and Adjustment
Broken dark lines across record	Caused by noise. Ground instrument from power cable to vessel ground plate or draw power from batteries rather than ship power.
Dark lines parallel to and just under water surface	Caused by direct return. Sound goes directly from pinger probe to hydrophone. Distance between water surface and line is twice the distance between the hydrophone and pinger probe. The presence of a direct arrival is not serious. It may be eliminated by reducing the initial gain.
Darkness between ocean bottom and surface	Ocean noise, reduce initial gain.
Intermittent white streaks across record	The pinger probe is either jumping out of the water or the transducer is being towed through turbulence. Air under the transducer faces attenuates the outgoing signal. The pinger probe can be moved out of the turbulence or the vessel speed reduced to lessen the effect of the surface conditions.
Multiple echoes of the ocean bottom	Multiples are not usually serious except when they coincide with sub-bottom layers. Multiples may be reduced by lowering the gain or output power level or placing the transducers on opposite sides of the wake.

e. **Side Scan Sonar Adjustments.** Darkness in water is usually caused by the wake of the boat or signal reflecting off the bottom of the vessel. The fish can be lowered or the other channel can be used.

2. **Maintenance.**

a. **Cleaning Writing Mechanism.** The writing mechanism is the only part of the recorder that requires frequent maintenance. Fine paper particles collect on the helix strip and prevent the current from passing between the helix strip and blade. The result is white streaks (parallel to the center of the paper) which can be removed with a damp sponge as shown in Fig. 22.

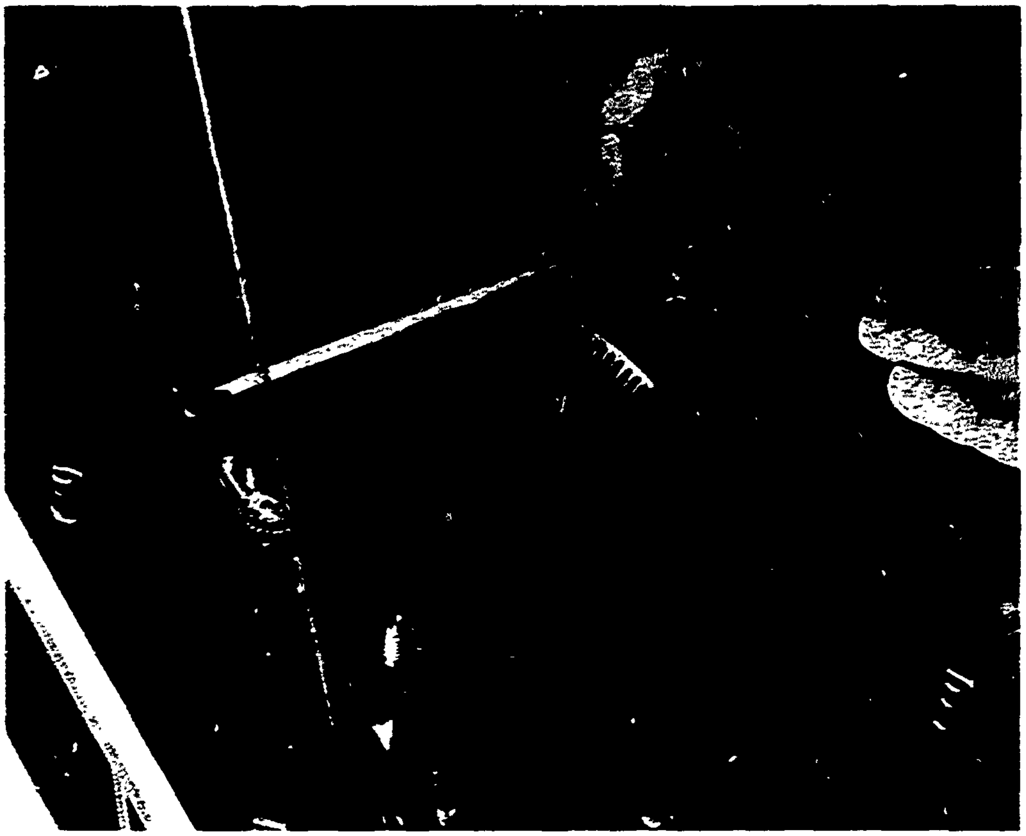


Fig. 22. Cleaning the helix strip.

If the clearance between the helix strip and blade is too small, the paper can be damaged to the point of causing holes in it, and keeping the helix strip clean is more difficult. Proper clearance between the helix strip and blade will minimize the problem.

b. Replacing the Helix Strip and Blade.

(1) If paper collects on the helix strip frequently and the quality of the printing decreases, it may be necessary to change the helix strip. As the strip ages, parts of it may become more flexible than others and it will be difficult to adjust the helix blade height so that it prints evenly without damaging the paper. If the helix adjustment is correct, the helix strip should be expected to operate more than 50 hours.

Both helix strips must be replaced at the same time or the problem will be compounded.

(2) If a fine light line appears to move diagonally across the record, there may be a nick in the helix blade. Since the helix blade moves slowly to distribute wear, the nick will move across the record. The helix blade can be turned over to eliminate the problem.

(3) A list of the most common problems and the causes are listed in Table II.

F. Record Interpretation

1. Acoustic Signature Correlation. AUSE was deployed over a wide variety of ocean bottom and sub-bottom composition. The acoustic signatures on the record were correlated to the sediment core logs so that general sediment types can be identified eventually by the acoustic signature without prior knowledge of the bottom.

The tests were conducted at the test sites shown in Appendix A.

Information on ocean bottom conditions was also used to identify surface conditions with the side scan sonar. The side scan was also used near known natural and manmade features so that they can be identified from the record.

2. Side Scan Sonar.

a. Target and Surface Identification.

(1) Read Record. The record is read most easily with the sub-bottom profiler portion at the bottom and the side scan sonar across the top.

Since the datum line of the side scan sonar channel represents zero time, it can be thought of as the transducer, since the signal is transmitted from the transducer. Distances measured from the datum line represent the radial distance from the transducer, not the water surface.

The scanning effect is obtained by printing the signals across the paper as they return. The closest target will appear first (near the inside of the record) because its reflection is returned first and is printed at the beginning of the sweep. Similarly, the farther targets will appear near the edge of the record, since they are received near the end of the sweep.

Table II. Troubleshooting Chart

	Problem	Cause and Solution
1.	No signal return on either channel (scale lines and event mark present: all PCB in place).	Use Built-In Test to determine if transducers are transmitting. Replace transducer driver cards.
		Insure that relay board is tight or replace the relay board (J6).
		Replace trigger board (J3).
2.	No signal returns on one channel.	Apply input Built-In Test. If no response (light line), replace sonar amplifier board for that channel (J7, 8, 9).
3.	No scale lines	
	a. On one channel.	Replace print amplifier for that side.
		Check fuse for that amplifier.
	b. Both channels.	Replace trigger/scale line generator card.
		Check +15-volt fuses.
4.	No event mark	
	a. On one channel.	Replace print amplifier for that channel (J2, J3).
	b. Both channels.	Replace +15-volt fuse.
5.	No TVG control.	Check negative ramp generator board. The TVG switch on this card must be pointing away from the operator for TVG to operate.
		Replace negative ramp generator board.
6.	No motor, no lights.	Check 8-amp fuse (F1).
7.	Motor operates, no printing.	Check +15-volt fuse (F2).
8.	Black over entire record.	Check -15-volt fuse (F3).
9.	No printing, no scale lines on starboard channel.	Check fuse (F4).
10.	No printing, no scale lines on port channel.	Check fuse (F5).
11.	Persistent fuse failure.	Pull all PCBs and replace one at a time to identify the PCB that is the source of the problem.
		If all PCB are good, but fuses continue to fail, power supply is the problem.
12.	No scale lines, dots moving across the record. Dark band at center of record.	Trigger lamp or helix drum is burnt out.

The ocean bottom is usually the first to be printed. That bottom profile will be the same as that seen on the sub-bottom profiler.

When the fish is towed close to the surface, the vessel's hull and wake may appear as a fuzzy line between the datum and the ocean bottom.

(2) **Acoustic Shadow.** Features having relief above the ocean floor block the outgoing beam so that the area immediately behind the feature is not insonified. This area is called the acoustic shadow and appears as a light area on the record. The outline of the acoustic shadow is analogous to the profile of the feature and may aid in its identification.

The acoustic shadow is used to calculate the height of the feature above the ocean floor. This method is described later.

(3) **Manmade Objects.** Manmade objects such as sunken ships are angular and have an acoustic shadow. Ships and barges, usually made of steel, leave a dense, dark signature.

Figure 23 shows auto bodies that were placed on the ocean floor as a fish haven. It is noted that: the targets are a marked change from the flat bottom around them; an acoustic shadow behind the auto bodies indicates relief; and the targets are dark and small, indicating a highly reflective, small object.

An object such as a piling (Fig. 24) will appear as a dot and may have a parabolic signature trailing behind. The parabolic signature indicates that the object is small and reflects energy that impinges on it from the edge of the beam.

(4) **Sand Bottom.** Sand is characterized by a light, smooth, slightly granular texture. Sand has sufficient strength to form wavelets when acted upon by current. Dredge cuts or anchor drag marks will appear with somewhat well-defined edges. Figure 25 shows a sand bottom with sand wavelets and a dredge cut with defined edges.

(5) **Mud Bottom.** Soft sediments, referred to collectively as mud, appear smooth, featureless, and somewhat dark. Mud does not have sufficient strength to form wavelets. Anchor drag marks, cuts, or mounds will appear to have rounded edges as will the acoustic shadows (Fig. 26).

(6) **Rock.** Rock areas appear dark and coarse in texture with discrete point targets and acoustic shadows behind each. Figure 27 shows a rocky bottom

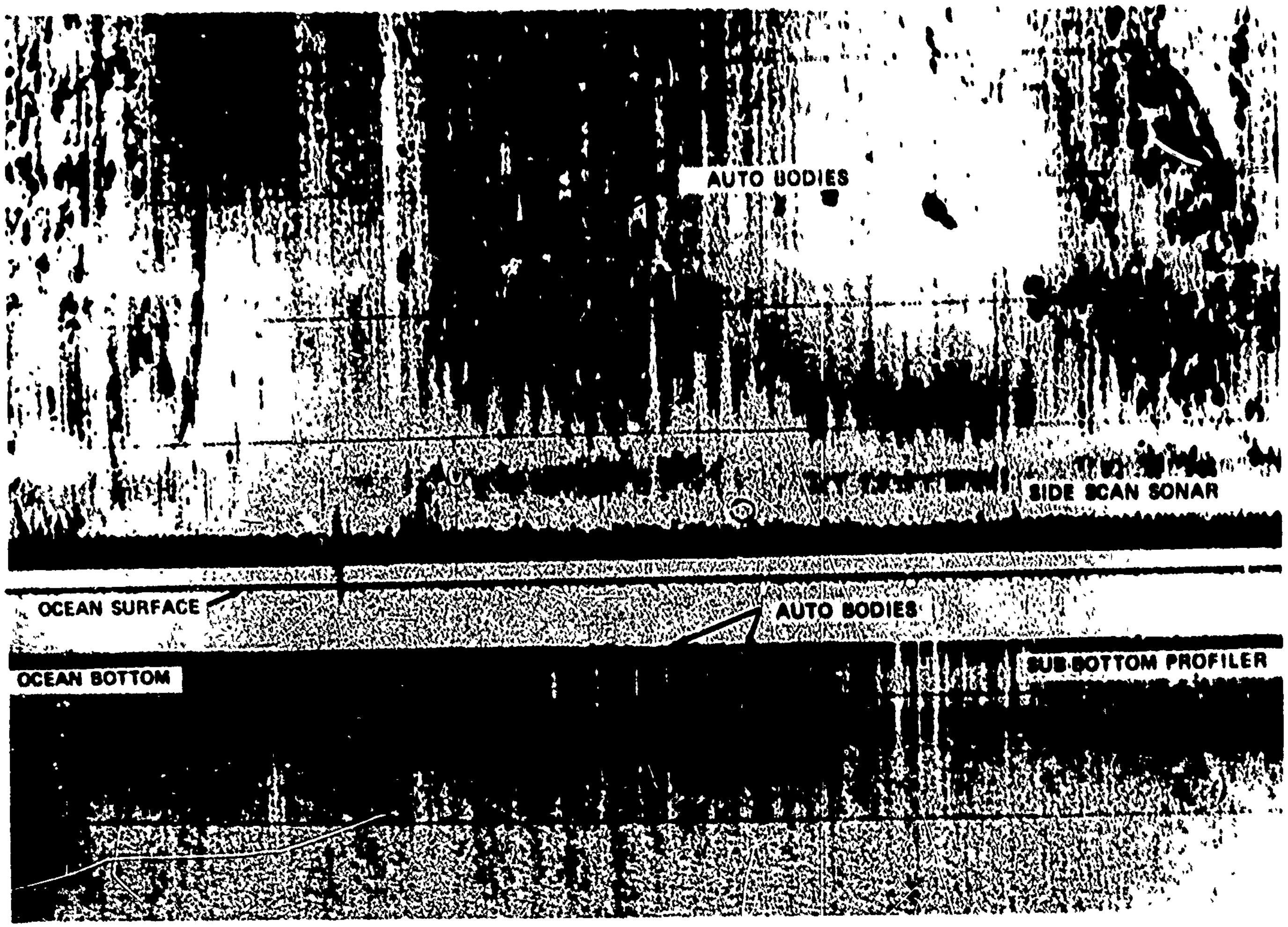


Fig. 23. Acoustic record—fish haven.

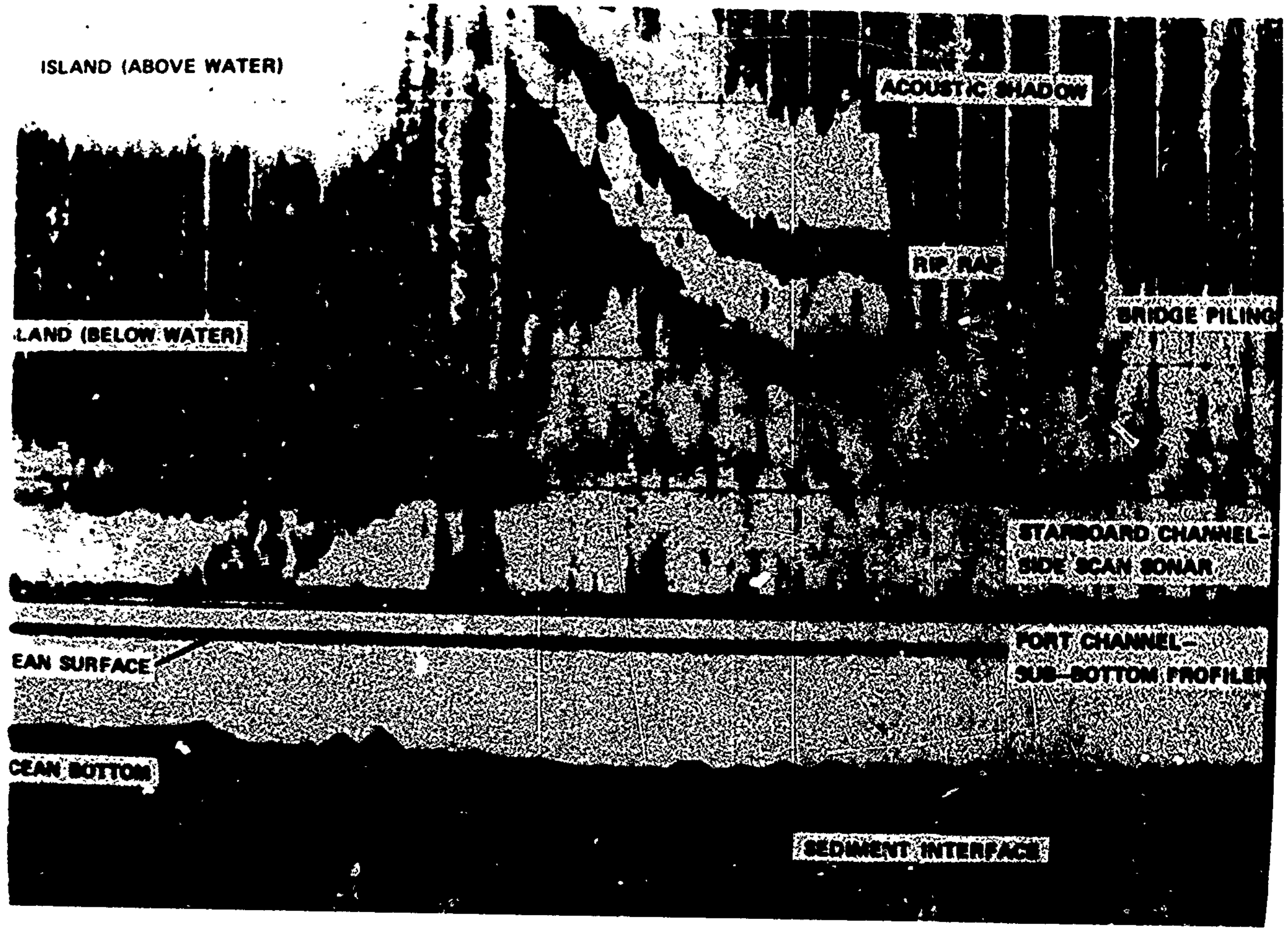


Fig. 24. Acoustic record–Chesapeake Bay Bridge-Tunnel.

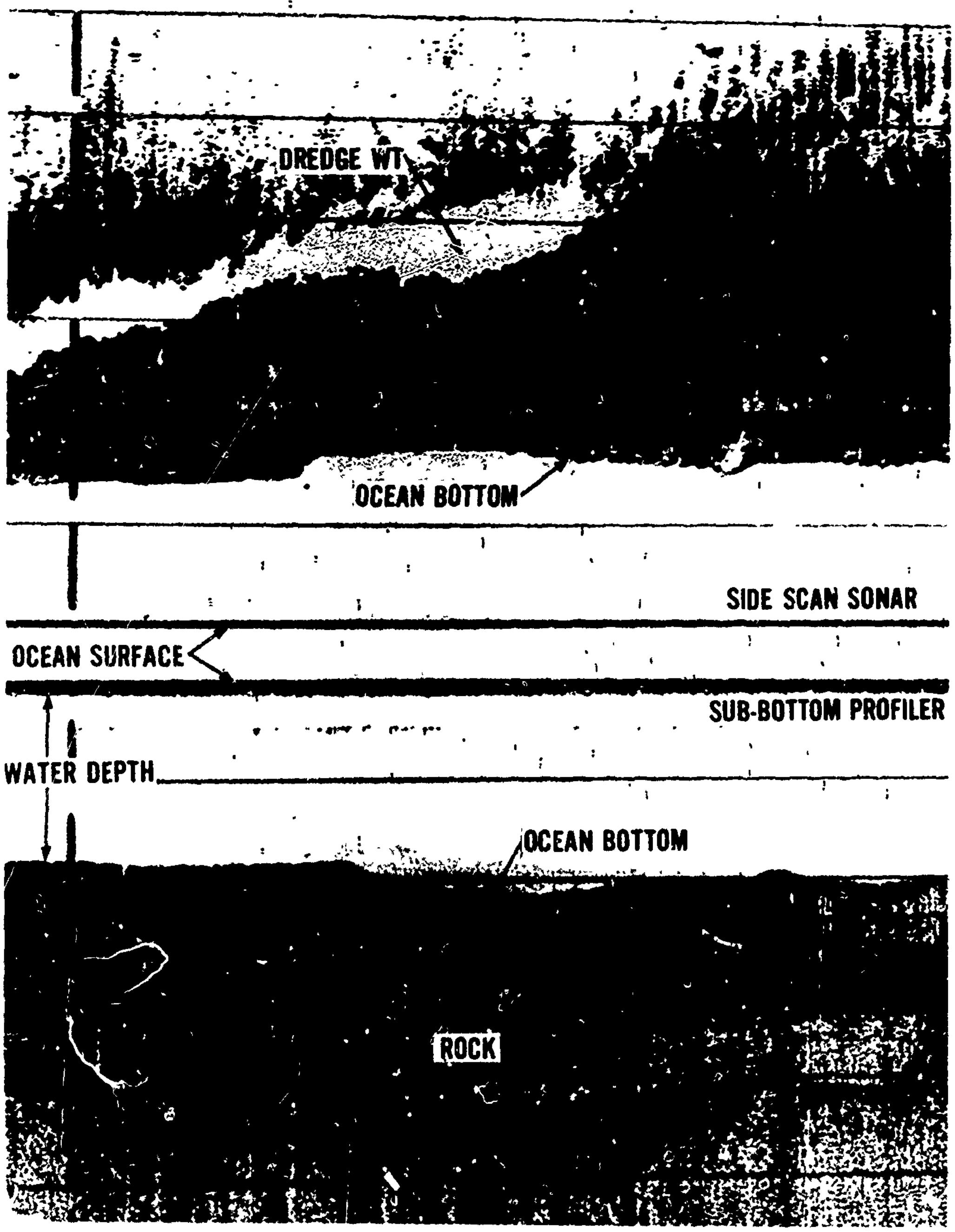


Fig. 25. Acoustic record—Baldhead Shoal Channel, Cape Fear River.

Fig. 26. Acoustic record—Thimble Shoals Channel, Norfolk, Va.

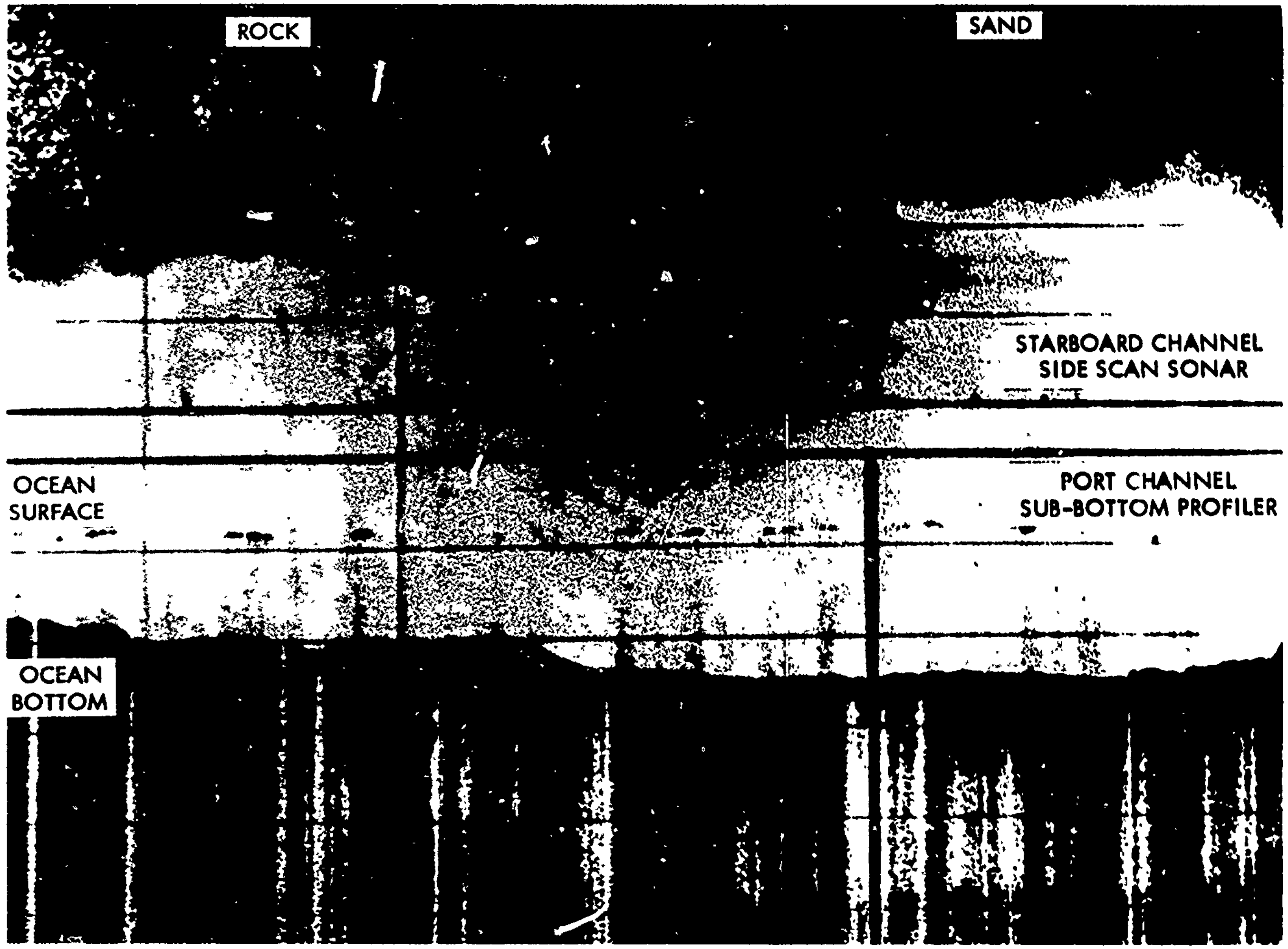


Fig. 27. Acoustic record—Salem Harbor, Mass.

adjacent to a sandy one. The rock bottom is rough in appearance, whereas the sand is smoother and has small sand wavelets.

Figure 24 shows the submerged portion of a rock manmade island. Riprap was placed around the bridge pilings to prevent scouring. The riprap shows up as a dark area. The acoustic shadow shows the rugged profile of the rock.

b. Target Dimensions.

(1) Spot Size. A graphic recorder such as the one incorporated in AUSE can display data with details as small as 1/50 inch. That is defined as the spot size and is also the smallest detail that can be detected with the human eye.

$$S = \frac{1}{50} \times \frac{R_s}{\text{Channel width}} \qquad (1)$$

where S = spot size

R_s = range scale (150, 300, 600 feet)

Since the width of one channel on the recorder is 5 inches, the spot size for the 150-foot range scale is

$$S = \frac{1}{50}\ \text{inch} \times \frac{150\ \text{feet}}{5\ \text{inch}} = 0.6\ \text{feet}$$

Therefore, no detail less than 0.6 feet can be displayed by the recorder. The spot size for the 300- and 600-foot scale is 1.2 feet and 2.4 feet, respectively.

(2) Range Resolution. Range resolution is the accuracy with which the side scan sonar can determine distances perpendicular to the vessel's path. Theoretically, an acoustic device should have a resolution of one-half the transmitted wavelength. Since the side scan is a 105-kHz device and the velocity of sound in water is approximately 5000 feet per second, the wavelength (λ) is

$$\lambda = \frac{5000\ \text{fps}}{105{,}000\ \text{Hz}} = 0.05\ \text{feet}$$

Therefore, the theoretical resolution is 0.025 feet. Since this is less than the spot size, the resolution is considered equal to the spot size. The

spot size of the recorder, not the wavelength of the transmitted frequency, is the limiting factor of the resolution of the equipment.

The range resolution depends on the range scale and, to some extent, the target strength, and is independent of the distance to the target or the vessel's speed.

The definition of the edges of the target could be in error as much as ½ λ on both the near and far edges of the target as discussed above. The distance, λ, must be subtracted from the recorded image to give the true dimension. Since the spot size is the controlling factor rather than the wavelength, the spot size is subtracted from the recorded dimension.

$$D_r = \frac{IR_s}{5} - S \qquad (2)$$

where D_r = true range dimension of the target (feet)

I = dimension of the image on the record (inches)

R_s = range scale

S = spot size (Table III)

The quantity $(\frac{R_s}{5})$ is called the range scale conversion factor and is used to convert the dimensions on the record to the true length of the target.

The spot size is small and can be deleted from the calculations in many cases.

Table III. Spot Size and Paper Rate

Range Scale R_s (ft)	Spot Size S (ft)	Paper Rate R_R (in./min)
150	0.6	5.0
300	1.2	2.5
600	2.4	1.25

(3) Angular Resolution. Angular resolution refers to the determination of target dimensions parallel to the path of the vessel. It is a function of beamwidth, target strength, and vessel speed.

The beamwidth (actually a combination of the transmit and receive beamwidths) is considered to be 1° wide horizontally with a 3-decibel decline at ½° to either side of the center of the beam. A strong target, one that reflects much of the energy that impinges upon it, will return energy from the edges of the beam (outside the ½°, 3-decibel limit), whereas a weaker target will not. The target will appear to be larger than it actually is. Gains should be kept low to minimize the effect.

A 1° beam will widen as it travels from the transducer, as shown in Fig. 28. Some energy is reflected back to the transducer after the center of the beam has passed the object. Therefore, the object will appear to be larger by one-half of a beamwidth at each end.

The true size of the target will be

$$D_a = I - B \tag{3}$$

where D_a = true dimension in the direction parallel to the direction of the vessel's travel

I = image dimension

B = beamwidth (see Fig. 28).

The angular scale conversion factor is derived using the basic equation of linear motion rate multiplied by time is equal to distance.

The rate at which the transducer moves past a target is equal to

$$V_g t = L_g$$

where V_g = velocity of the vessel over the ocean floor.

L_g = length on the ground traversed in time, t.

t = time.

The same area is recorded on the recorder chart.

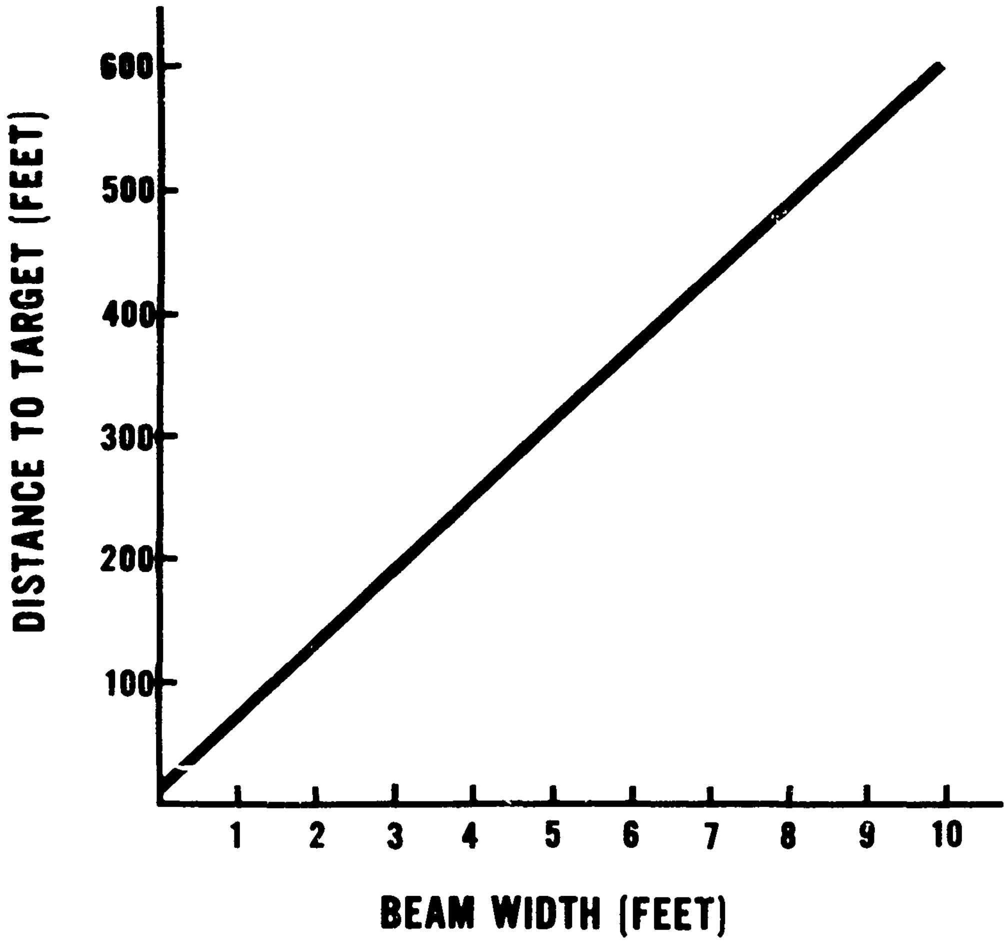


Fig. 28. Beamwidth.

Therefore,

$$R_r t = L_r$$

R_r = rate at which the paper moves out of the recorder (Table III).

L_r = length on the record traversed in time, t.

Since AUSE is a real-time instrument, the times, t, in the equations are set equal to obtain a ratio between the actual target size and the recorded target size.

$$\frac{L_g}{V_g} = \frac{L_r}{R_r}$$

$$L_g = L_r \times \frac{V_g}{R_r}$$

The term $\frac{V_g}{R_r}$ is the angular scale conversion factor. Substituting the above factor into equation 3,

$$D_a = L_r \frac{V_g}{R_r} - B \tag{4}$$

To detect targets at a great distance from the vessel, it is advantageous to decrease the vessel's speed so that the smaller targets are printed larger than they would be at a greater speed.

If a target is so small that only one pulse is reflected from it, it will appear as a dot on the record. Only its presence, rather than its dimensions, can be determined.

(4) **Oblique Dimensions.** The dimensions of targets lying oblique to the vessel's path must be calculated by resolving the target dimensions into components in the range and angular directions and obtaining the vector sum. This is necessary because two time scales are present on the perpendicular directions of the record. Referring to Fig. 29,

$$L_T = \vec{L}_1 + \vec{L}_2$$

$$W_T = \vec{W}_1 + \vec{W}_2$$

where L_T, W_T = true length and width, respectively

L_1, W_1 = length and width components perpendicular to the vessel's path (angular direction)

L_2, W_2 = length and width components parallel to the vessel's path (range direction)

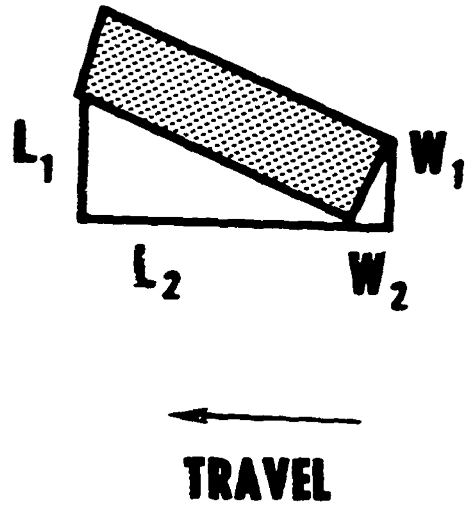


Fig. 29. Oblique targets.

Referring to equations 2 and 4,

$$L_T = \sqrt{\left(L_2 \frac{V_g}{R_r} - B\right)^2 + \left(L_1 \frac{R_s}{5} - S\right)^2} \qquad (5)$$

$$W_T = \sqrt{\left(W_2 \frac{V_g}{R_r} - B\right)^2 - \left(W_1 \frac{R_s}{5} - S\right)^2} \qquad (6)$$

(5) **Height of Targets.** The height of a target can be determined by using a simple geometric relationship. Referring to Fig. 30(a),

$$\frac{h}{r} = \frac{H}{R+r}$$

$$h = \frac{rH}{R+r} \qquad (7)$$

where h = height of the target

r = length of the acoustic shadow measured from the record (inches)

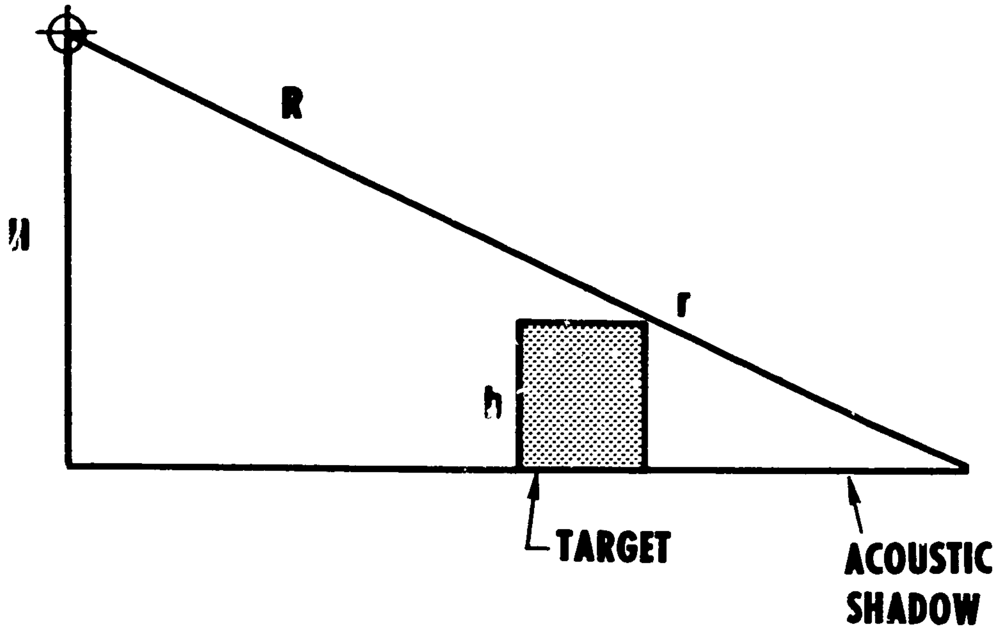


Fig. 30(a). Relief of a target above the ocean floor.

R = distance to the target on the record (inches)

H = height of the transducer above the bottom of the record (inches)

Applying the range scale conversion factor to equation 7,

$$h = \left(\frac{rH}{R+r}\right)\left(\frac{R_s}{5} - S\right) \tag{8}$$

where the height of the target (h) is in feet.

The height of targets at an oblique angle to the vessel's path can be determined in the following way.

Figure 30(b) represents one channel of a side scan sonar record, showing a target at an a[illegible]le to the vessel's path. The height of the target is calculated as follows:

Using equations 5, 6, 8,

$$r = \vec{r_1} + \vec{r_2}$$

$$= \sqrt{\left(r_1 \frac{V_g}{R_r} - B\right)^2 + \left(r_2 \frac{R_s}{5} - S\right)^2} \qquad (9)$$

$$h = \frac{r\left(H \frac{R_s}{5} - S\right)}{\left(R \frac{R_s}{5} - S\right) + r} \qquad (10)$$

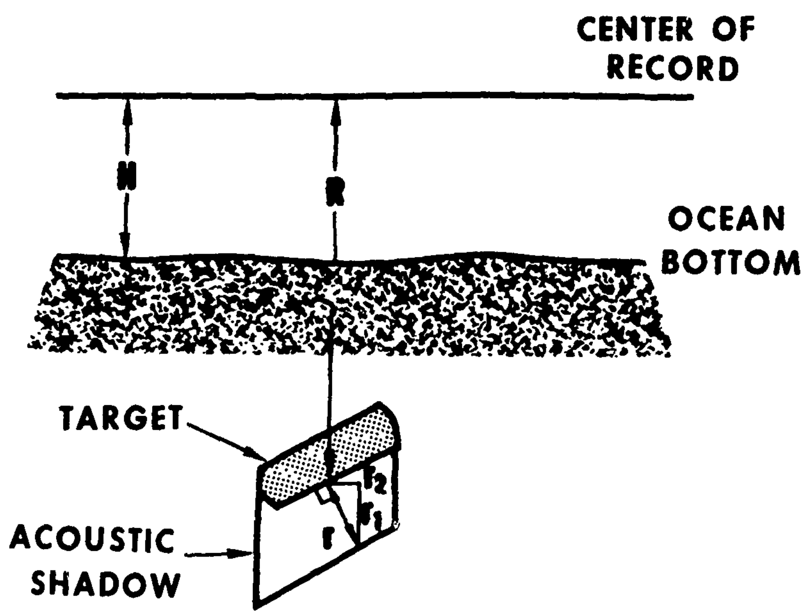


Fig. 30(b). Relief of oblique target.

(6) **Lateral Distance.** The distances measured on the record perpendicular to the centerline are radial distances from the transducer to the target. The lateral distance from a point on the ocean bottom directly below the transducer to the target is calculated in the following manner.

Referring to Fig. 31,

$$d_r^2 = H^2 + d_L^2$$

$$d_L = \sqrt{d_r^2 - H^2} \qquad (11)$$

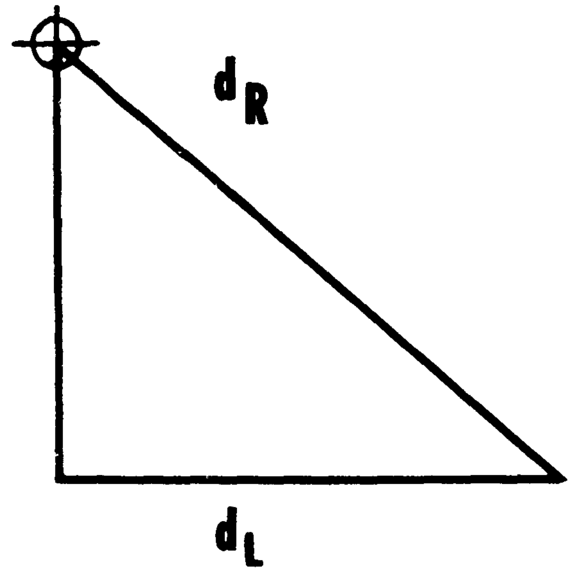


Fig. 31. Radial-lateral distance relationship.

where d_L = lateral distance from a point on the ocean bottom below the transducer to the target.

H = height of the transducer above the ocean bottom as measured from the record (inches).

d_r = radial distance to the farthest point of the target on the record (inches).

Applying the range scale conversion factor to equation 11,

$$d_L = \left[\sqrt{d_r^2 - H^2}\,\right]\left(\frac{R_s}{5} - S\right) \tag{12}$$

The relationship between the radial and lateral distances is shown in Fig. 32. It is noted that the difference between the two distances is small when the transducer is close to the ocean floor.

c. Transducer Depth and Water Depth Measurements. The centerline of the record represents the transducer where the signal originates. Since the fish is not at the surface, the centerline does not represent the water surface as it does for the

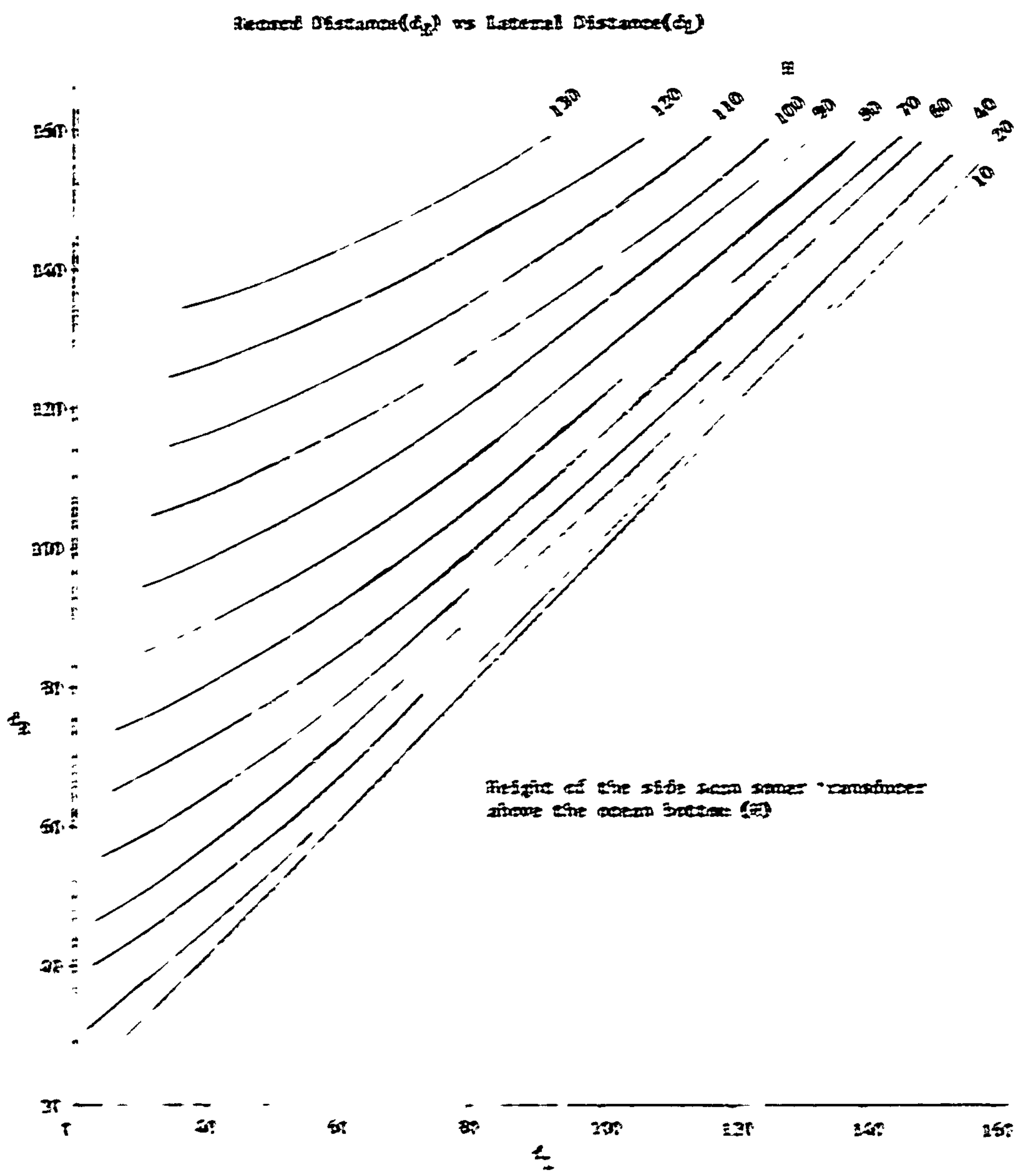


Fig. 32 Radial distance corrections on side scan sonar record.

sub-bottom profiler. Since the ocean bottom directly under the transducer is the closest target, it is the first to be printed. The height (H) of the transducer above the ocean floor can therefore be measured from the record as shown in Fig. 33.

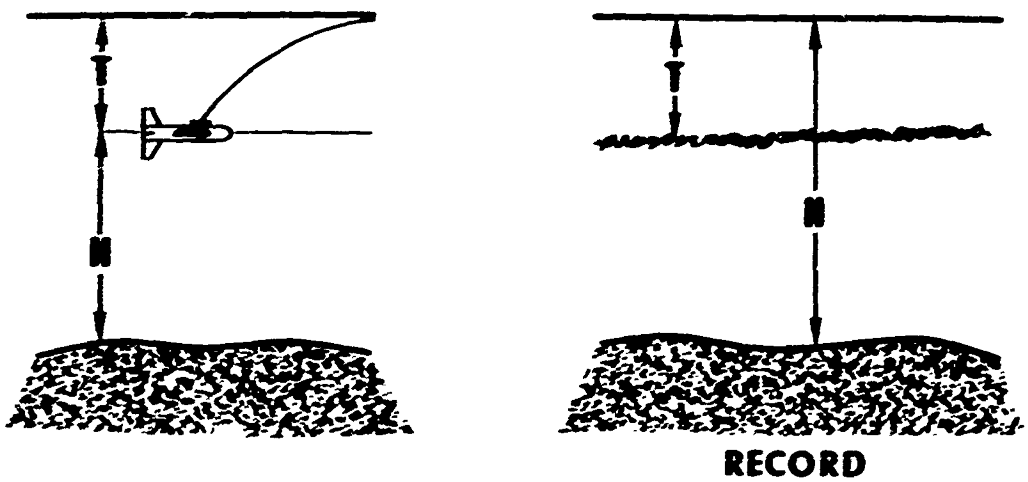


Fig. 33. Height of side scan sonar fish above the ocean bottom.

When the side scan sonar fish is towed under the boat, the signal will reflect off the hull and wake of the vessel and appear on the record.

Referring to Fig. 33, T is the depth of the transducer below the surface. The sum of H and T is the water depth. Applying the range scale conversion factor,

$$\text{Water depth} = (T+H)\left(\frac{R_s}{5} - S\right).$$

This figure can be checked with the water depth obtained from the sub-bottom profiler.

3. Sub-Bottom Profiler.

a. Resolution. The wavelength of the sub-bottom profiler is

$$\lambda = \frac{5000 \text{ fps}}{5000 \text{ cps}} = 1 \text{ ft.}$$

The theoretical resolution is equal to one-half the wavelength, or 0.5 feet. Because of the limitations discussed above, the actual resolution is equal to the spot size of the records (Table III).

b. **Multiple Reflections.** A multiple reflection occurs when the signal transmitted by the pinger probe reflects back and forth between the ocean bottom and the water's surface several times before being received at the hydrophone. Since a pulse traveling that path requires two, three, or more times longer to reach the hydrophone than a pulse reflecting from the ocean bottom and going directly to the hydrophone, the signature of ocean bottom will appear several times on the record. Each is called a multiple because it is located at a distance from the water surface equal to an even multiple of the water depth. The presence of multiples is of no concern unless the water is so shallow that the multiples coincide with sub-bottom layer signatures. Multiples may be eliminated by placing the pinger probe and hydrophone on opposite sides of the wake so that the turbulence will attenuate the pulses that reflect on the water's surface between the pinger probe and hydrophone.

c. **Direct Returns.** A direct return is produced by a pulse traveling directly between the pinger probe and hydrophone without reflecting off the ocean bottom. It appears as a line parallel to and just below the water's surface on the record. This line represents twice the distance between the pinger probe and the hydrophone. It can be used in the calculations to determine the actual water depth from the sub-bottom profiler record.

d. **Water Depth Determination.** A pulse from the sub-bottom profiler can be thought to follow the path shown in Fig. 34. The water depth indicated on the record (d_i) is somewhat greater than the actual depth (d). Using the equation

$$\left(\frac{Sp}{2}\right)^2 + d^2 = d_i^2$$

the actual water depth is equal to

$$d = \sqrt{d_i^2 - \frac{Sp^2}{4}}$$

where Sp is the hydrophone-pinger probe separation.

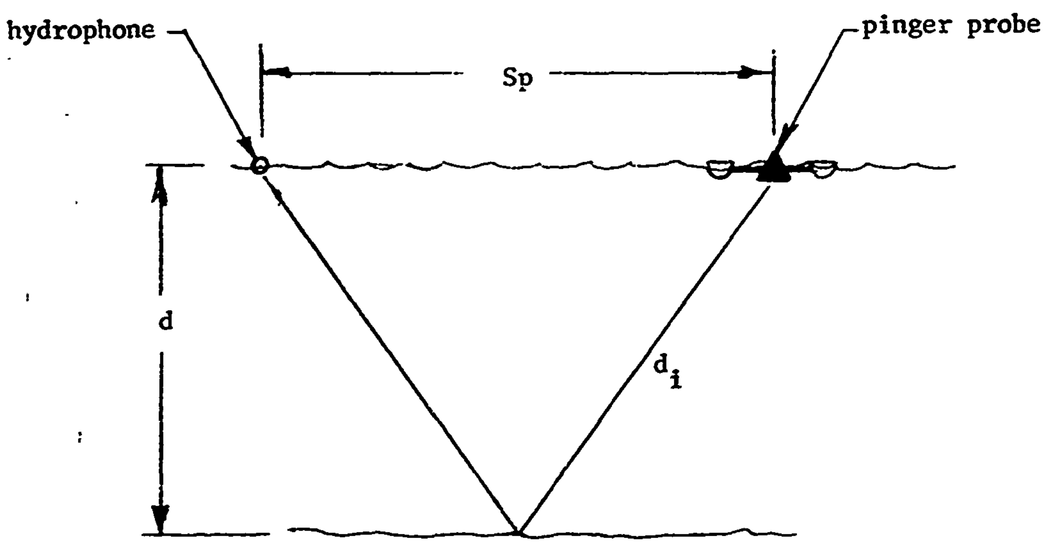


Fig. 34. Effect of transducer separation on recorded water depth.

If the separation of the hydrophone and pinger probe is taken from the record (i.e., direct return). the above equation becomes

$$d = \sqrt{d_i^2 - \frac{Sp^2}{16}}$$

Figure 35 shows the effect of separation on the indicated waer depth.

e. **Identification of Sub-Bottom Sediment Layers.**

(1) **Descriptions of Acoustic Signatures of General Sediment Types.**

(a) **Sand.**

1. A sand bottom is a dark. thin line with even light brown underneath.

2. The first multiple is a sharp line. Because sand is a good reflector. there may be more than one multiple.

3. A sand sub-bottom layer appears as a dark, sharp line

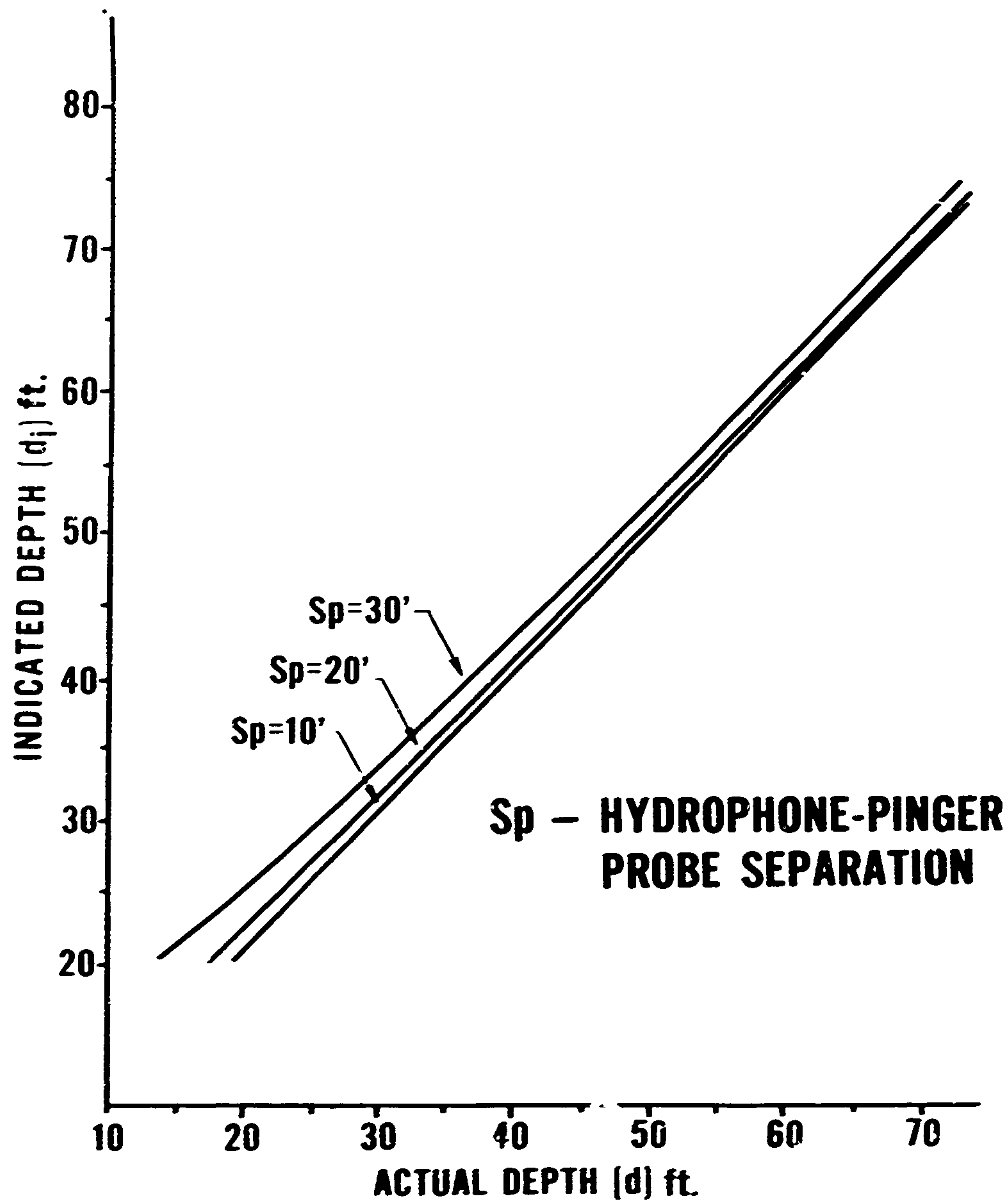


Fig. 35. Recorded depth vs actual depth on sub-bottom profiler record.

4. A silty sand bottom appears as a dark sharp line with a light granular area underneath.

(b) Mud.

1. A mud bottom is characterized by a diffuse line. The area under the bottom is dark and there is no apparent distinction between the ocean bottom and the area immediately underneath. The acoustic signature of mud may be considered a "volume" reflection rather than a surface reflection.

2. A mud sub-bottom layer appears the same as a mud bottom.

(c) Clay. A clay bottom or interface appears as a dark line much the same as a sand bottom. The area immediately under the clay bottom line will be somewhat darker than the area immediately under a sand bottom line.

(d) Rock. A rock bottom appears rough and irregular. The area under the bottom is dark and there is no apparent penetration.

(e) Coral.

1. The acoustic signature of coral heads is the same as rock on both the sub-bottom profiler and the side scan sonar. Coral occurs in specific areas where rocks are not usually present. The coral in some areas is so hard that it is marked as rock on nautical charts.

2. Some coral areas appear the same as compact sand. Since the EEA can be deployed successfully in either, there is no need to distinguish between the two.

(2) Qualitative Distinction.

(a) Because sand is a good reflector of acoustic energy, the sub-bottom interfaces under sand will not appear to be strong.

(b) Because mud transmits acoustic energy well, the sub-bottom interfaces under mud will appear to be strong.

(c) Multiple reflections of bottom sediment are

1. Sand–sharp line with several multiples.

2. Mud–diffuse line with dark area underneath. Generally not more than one multiple.

3. Clay–sharp line with dark area underneath.

4. Rock–pronounced first multiple.

(3) **Sub-Bottom Sediment Identification Chart.** The above descriptions have been organized in chart form and appear in Fig. 36. The chart is entered at the top and the appropriate lines followed in accordance with determinations made while analyzing the sub-bottom profiler records.

G. Engineering Design Tests.

AUSE was tested at a number of sites on the east coast of the United States. A detailed discussion of each test would not be useful, but the pertinent points of these tests follow.

1. **Modification to Circuitry.** During the operator training course and tests in the Chesapeake Bay mouth, it was noted that the acoustic signatures appearing on the record were printed as a series of fine lines close together rather than one wider line. Although this is advantageous in detecting fine details in the stratigraphy, it lessens the operator's ability to identify general sediment types.

The circuitry of AUSE was modified to give the desired width of acoustic signature. A potentiometer was added to the circuit so that the appearance of the signature could be altered for a geophysical survey, for example, where detail is desired. Extreme care must be exercised in returning the potentiometer to the proper setting or the interpretation of the recorder over bottoms where no previous sub-bottom information exists will be difficult.

2. **Depressor Test.** The effects of the depressor on the side scan sonar transducer were determined during a test at Key West, Florida.

The side scan sonar transducer was deployed on 120 feet of cable without a depressor. At speeds of 5 to 7 knots, the ratio of the side scan transducer depth to the water depth is approximately 0.1. The addition of a depressor at the midpoint of the cable and one at the transducer increases the ratio to approximately 0.2 to 0.4. Therefore, the depth of the side scan fish can be increased from two to four times with a

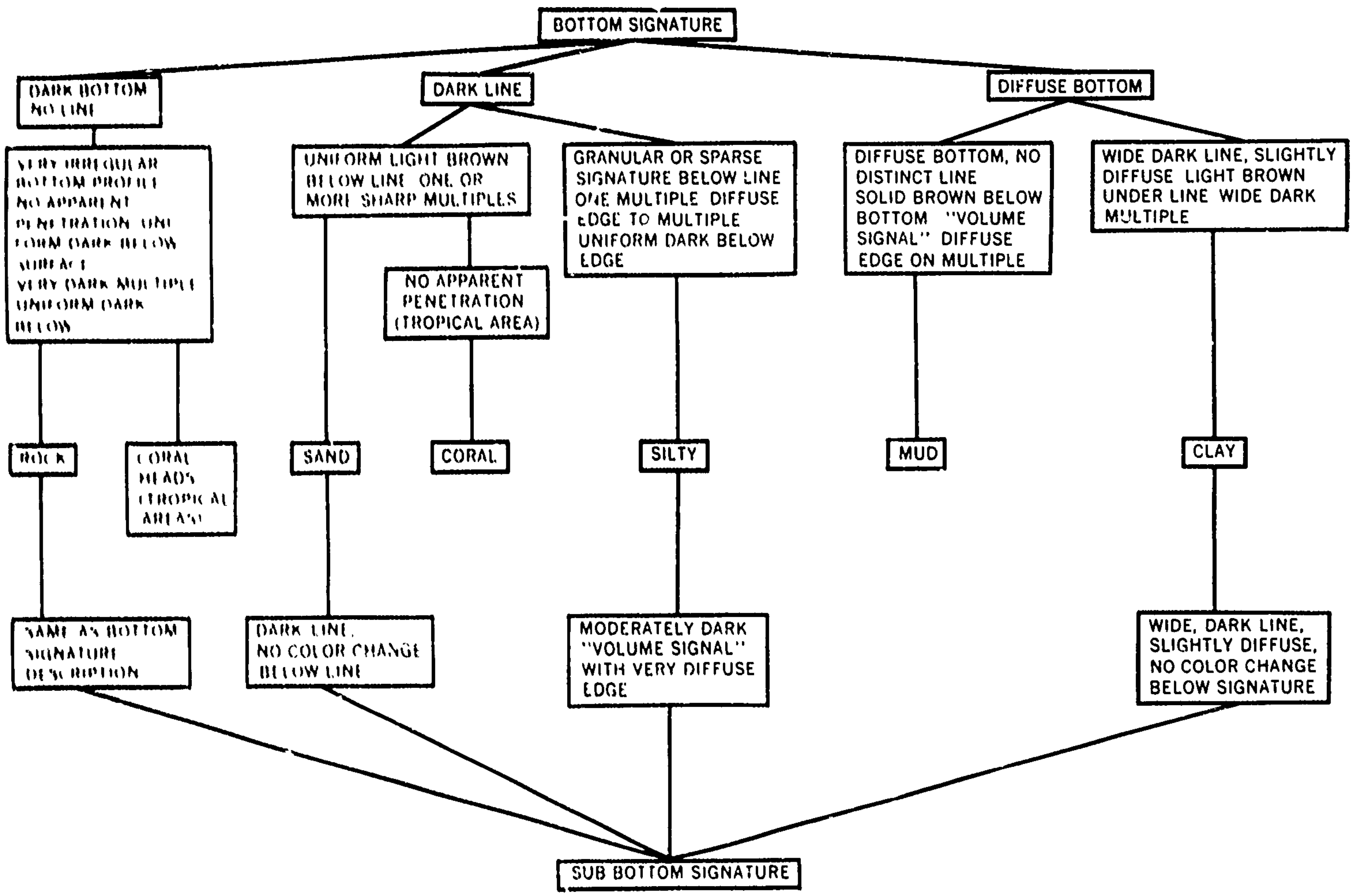


Fig. 36. Sub-bottom sediment acoustic signature identification chart.

depressor. Decreasing the vessel's speed will increase the ratio in addition to the figure cited above.

At 5 to 7 knots, the cable tension was approximately 150 to 175 pounds. The weight of the transducer and depressors in water is approximately 60 pounds.

3. **Shipping Chests.** Military Standard wooden shipping chests for the equipment were supplied by EG&G under the terms of the contract. Shock and vibration tests were to be performed on the chests to determine their ability to protect the equipment.

The side scan sonar and pinger probe chests were so weakened by air freight shipment to several EDT sites before the test that they were not tested for fear that the equipment might be damaged. The recorder chest was tested by Associated Testing Laboratories, Inc., Burlington, Massachusetts, and sustained minimal damage. The recorder appeared to sustain no damage.

The handles on all three chests were not of the spring-loaded type (the type specified by the contract) and most had been pulled off during shipment and were missing at the time of the test.

4. **Motor Surf Boat Leakage.** During all EDT conducted in rough and windy conditions, water leaked into the shelter cabin of the MSB through the ocean between the gunwales and the shelter cabin and through the hatch. While this condition does not limit or eliminate the operation of the equipment, it does detract from the comfort of the operator.

H. Survey Procedures

1. **Tactical (Normal).** A tactical survey (normal) is a survey performed in support of the Multi-Leg Tanker Mooring System for which sufficient time is available to perform all steps of the survey thoroughly.

a. **Concept.**

(1) **Side Scan Sonar Survey.** The large area offshore from the beach head (Fig. 37) will be surveyed with the side scan sonar (600-foot scale) to locate any hazards to navigation in the mooring or its approaches. Approximately 45,600 feet of ocean bottom will be surveyed. At a speed of 5 knots, the survey will require approximately 1.5 hours to complete.

(2) **Sub-Bottom Profiler Survey.** If the area is free of obstructions, a small portion of the area closest to shore is surveyed in detail with the sub bottom

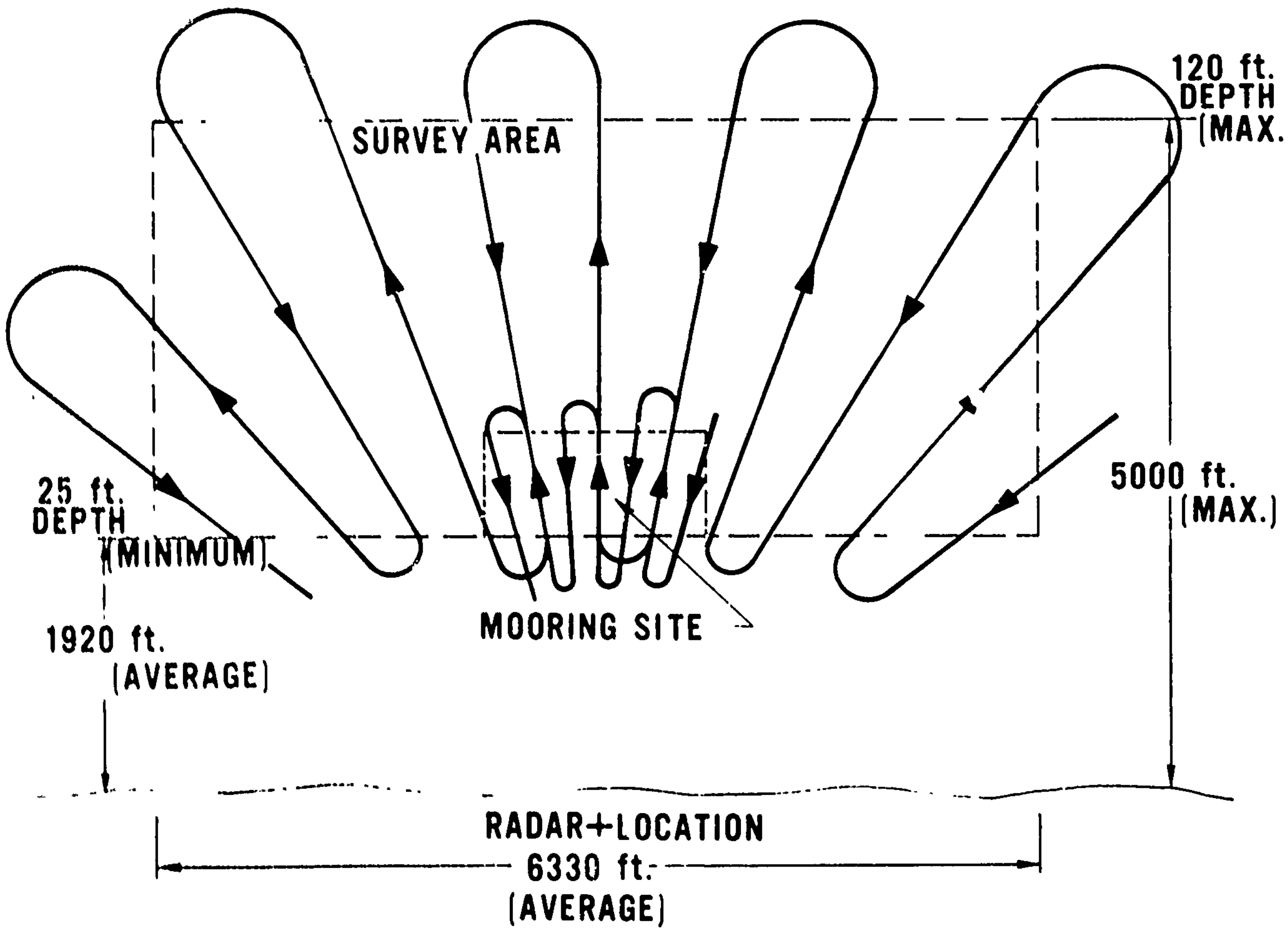


Fig. 37. Tactical survey layout.

profiler. This is the area where the Multi-Leg Mooring System will be deployed. The time required for this survey is approximately 25 minutes.

(3) **Position Control.** An AN/PPS-5 radar set onshore plots the course of the Motor Surf Boat. The radar operator will radio course corrections to the MSB operator to insure that the boat remains on course.

Since the AN/PPS-5 radar set is a range-azimuth type instrument, the operator must read both the range to the MSB and the angle between the MSB and some arbitrary baseline. The rate at which readings can be taken (i.e., the position plotted) can be increased by using a radial survey layout in which the MSB travels along a given azimuth line. The radar operator must determine only the range from the radar set to the MSB and give course corrections as necessary if the MSB deviates from the azimuth line.

Once a minute, the position of the MSB is marked with a number on the plotting board and that number radioed to the MSB. The event marker on the recorder is depressed and the number noted on the margin of the record next to the event mark line. A direct correlation is thereby established between a feature on the record and its position on the ocean bottom.

b. **Survey Site Layout.** The dimensions and layout of the survey site are as follows (Fig. 37).

(1) **Seaward Boundary.** The seaward boundary of the survey site is defined as the 120-foot water depth contour or 5000 feet from shore, whichever occurs first.

The 120-foot depth limit is the maximum practicable operating depth of the scuba divers who are essential participants in the deployment of the Multi-Leg Tanker Mooring System. The 5000-foot limit is the maximum distance off-shore that can be reached by the tactical pipeline that will service the tanker.

(2) **Near-Shore Boundary.** The near-shore boundary is the 25-foot water depth contour. Studies have shown that depth to occur at an average of 1920 feet offshore from the beaches under consideration for military operations.

(3) **Width.** The width of the entire survey site is equal to the length of the adjacent beachhead. Studies have shown that the average length of the beaches under consideration is 1.2 miles.

(4) **Mooring Area.** The smaller area that is surveyed in detail with the sub-bottom profiler is a rectangle of 1700 feet by 800 feet. This area should be as close as possible to the near-shore boundary, but it may be placed anywhere within the survey area to obtain the desired bottom and sub-bottom conditions.

(5) **Side Scan Sonar Survey Layout.**

(a) **Side Scan Sonar Search.** The survey lines should be approximately 10° apart (Fig. 37). This will allow a 200-foot overlap of the records of two adjacent lines at the boundaries and full overlap near the bottom and center. The MSB, therefore, can deviate 100 feet in opposite directions on adjacent lines and full coverage will be maintained.

(b) **Sub-Bottom Profiler.** To obtain a high concentration of sub-bottom composition information, the survey lines should be approximately 200 feet apart at the farthest point. Following azimuth lines approximately 5° apart will provide adequate spacing.

c. **Data Mapping.** For ease of planning and quick reference, the information obtained from the surveys can be marked on the plotting board used by the radar operator.

(1) **Side Scan Sonar.** All obstructions detected by the side scan sonar will probably be of two types and should be marked accordingly:

(a) **Navigational Hazards.** Obstructions of sufficient size to damage a vessel should be marked and the clearance over them noted.

(b) **Debris.** Areas of debris and rocks should be noted so that EEA will not be fired or the pipeline installed in that area.

(2) **Sub-Bottom Profiler.** As the records are interpreted, points on each survey line where satisfactory sediments are not at least 12 feet deep should be marked. After all the records have been interpreted, a line can be drawn through all the points and the area of inadequate sediment conditions enclosed and marked

2. **Tactical (Hasty).** A tactical survey (hasty) is a survey performed in support of the Multi-Leg Tanker Mooring System in which time requirements or adverse circumstances have dictated that a complete survey not be performed initially and that construction begin immediately.

a. **Concept.** In a situation where the shortage of time is critical, the side scan sonar survey can be delayed or foregone entirely and the actual mooring site surveyed with the sub-bottom profiler and side scan sonar.

There are inherent risks in this method since nothing is known about the area outside the actual mooring site, and it is possible that a subsequent side scan survey might limit or eliminate the site.

b. **Survey.** The survey is conducted by following the lines in the smaller area in Fig. 37. The area that the MSB has not yet entered should be printed on the side scan sonar. This is accomplished by setting the Mode Switch at the beginning of each line so that the side scan sonar is "looking" toward the position of the mooring site that has not yet been surveyed. This procedure will warn the MSB operator of hazards.

Position control and data mapping procedures are the same as above.

3. **General Side Scan Sonar Search (Administrative or Non-Military).** Described below is a general procedure that can be followed when the side scan sonar is deployed in a non-tactical situation (e.g., Engineer Districts). It is assumed that a commercial range-range radar positioning system is used and that a rectangular survey grid is therefore in order.

In searching for a medium size object (e.g., sunken boat), the 300-foot or 600-foot scale may be used. Since the transmitted beam is narrow close to the transducer, it would be possible to miss a medium size target located within the inner one-third of the record. To provide 100 percent coverage and insure that the target will not be missed, the survey lines should be parallel and alternately spaced 1000 feet and 200 feet apart (for the 600-foot scale). This provides overlapping beam patterns in the inner one-third of the record (Fig. 38).

I. AUSE Operator Training and Utilization

1. **Operator Training Course.** A training course was conducted by EG&G to instruct enlisted Soils Analysts (MOS 51G) in the use of AUSE and assess their ability to operate the equipment and interpret the records.

Two Soils Analysts were detailed to USAMERDC from the U.S. Army Engineer School Brigade for the training course and used on an intermittent basis thereafter. Because of a troop strength reduction being imposed at that time, difficulty was encountered in obtaining the desired number of Soils Analysts with a variety of backgrounds.

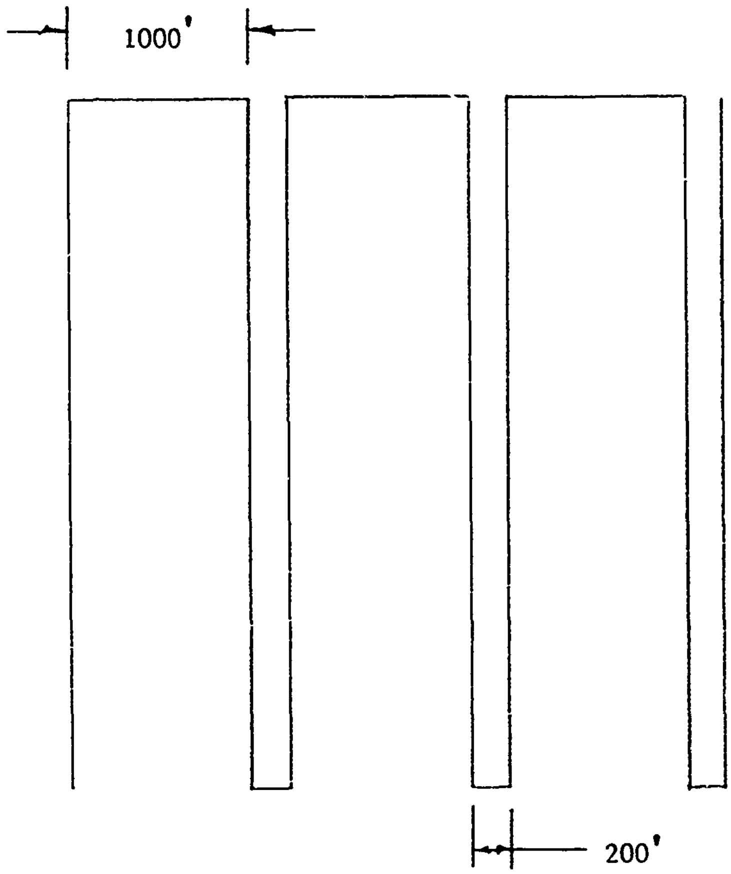


Fig. 38. General side scan sonar search pattern.

The educational level was somewhat higher than the typical Soils Analysts who might be trained to operate the equipment.

The manual writer responsible for the compilation of the technical manual for the AUSE also participated in the training course.

a. **Training Course Structure.** The training course was intended to be approximately 10 days. It was found that only 6 to 7 days were necessary to cover the materials thoroughly but without repetition.

Approximately 2 days were spent familiarizing the student with the equipment and explaining the function of the controls. The next 3 days were spent in "hands-on" training so that the student could benefit from operating the equipment on a vessel. During a second class session, specific questions were addressed and the

fundamentals reemphasized and expanded in light of the shipboard experience. The course outline is shown in Appendix F.

Alternate classroom and shipboard training sessions were useful because it was found that the students understood the equipment much better after operating it.

b. Conduct of the Training Course. The classroom portion of the training course was held at the Environmental Equipment Division of EG&G in Waltham, Massachusetts, where classroom and laboratory facilities were made available. A test tank filled with water of standard salient was used to demonstrate some aspects of the equipment.

The shipboard portion of the training course was conducted aboard the motor yacht Sea Legs out of Marblehead, Massachusetts. Records were taken in Salem and Boston Harbors and along the coast between Boston and Gloucester, Massachusetts. A variety of ocean bottom and sub-bottom conditions are available in these areas. Penetrations in excess of 100 feet were obtained on the softer bottoms in that area. The side scan sonar detected extensive rock bottoms.

The side scan sonar transducer was lost one-half nautical mile off Gloucester in 75 feet of water (42° 35.07'N, 70° 38.2'W). Lobster traps are tied together in groups of 15 to 20, and the end traps marked with a buoy and line. A marker buoy line apparently became wrapped around the side scan sonar transducer tow cable and the extreme weight of the traps caused the cable to fail. The record shows that the fish was pulled down just before the cable failed. A diver from Gloucester was taken to the area, but the transducer could not be found. Although visibility was good, strong currents hampered search efforts.

c. Results and Evaluation of the Training Course. The following remarks pertain to the training course and should be applied to the organization of future courses:

(1) Sample records should be available during the course so that the students can identify the various bottom sediments.

(2) Simplified block diagrams of the circuitry should be used.

(3) Technical aspects of the equipment should be limited. Practical applications are of more use to the student.

(4) Classroom training should be limited; shipboard "hands-on" experience is the most valuable phase of training.

(5) Printed circuit boards with known malfunctions should be used so that the student can practice troubleshooting the equipment.

(6) The shipboard portion of the training should be conducted over known bottoms where a variety of sediments can be found.

The trainees felt that they could tell what the bottom sediments were with the help of the side scan sonar. They were not sure of their ability to distinguish the various sub-bottoms. That, however, was not emphasized during training, because the circuitry was going to be modified to give a different acoustic signature.

The course must be short and thorough to keep the students' interest. Excessive classroom training becomes repetitive and extensive collection of records becomes nonproductive and boring.

The experience of the operator appears to be the single most important factor in the successful deployment of AUSE. Therefore, a short, thorough training course followed by actual geophysical surveys for Army agencies appears to be the most productive means of training an operator and maintaining his proficiency.

2. **Civil Works Assistance Surveys.** As stated above, operator experience is the key to successful deployment of AUSE. To provide the AUSE operator with the opportunity to practice and improve his skill outside the classroom, sub-bottom profiler surveys were arranged with several Districts of the U. S. Army Corps of Engineers. The surveys were conducted to:

a. Collect records over known ocean bottoms for further correlation of the acoustic records.

b. Provide the operator with the opportunity to collect and interpret records.

c. Establish the effectiveness of the enlisted personnel as sonar operators and to assess the merits of the Soils Analysts (MOS 51G), in particular, as operators.

d. Support the Civil Works programs of various District Engineers.

A number of Districts were contacted and a survey was performed for the Wilmington District in November 1971. The survey included parts of the Cape Fear River and the Atlantic Intracoastal Waterway. A large quantity of useful information was collected in support of a project to increase the depth of those two waterways.

3. **Survey of Utilization by Army Agencies.** Equipment such as AUSE is used commercially in sand inventories, predredging surveys, harbor facilities preconstruction surveys, and search and salvage operations. In addition to its intended military mission, AUSE could be used by the Army for:

a. **Emergency Search and Salvage Operations.** The prototype AUSE was deployed in November 1970 at the request of the Philadelphia District of Army Corps of Engineers when a vessel sank in the Delaware River and was considered a hazard to shipping. The AUSE was under test in the Santa Barbara (California) Channel, and was transported to the Delaware River where it was successful in locating the vessel. AUSE has the advantage of being lightweight, compact, and easily transported, and it can be operated from a vessel of any size.

It is estimated that the use of side scan sonar in place of conventional fathometer methods reduces the search time by 95 percent.

b. **Short Geophysical Surveys as Part of Larger Construction Projects.** Frequently, a small amount of geophysical work is required in support of a larger construction project. AUSE could provide these services on short lead time and at low cost. Short surveys, though often very beneficial to the overall project, are relatively expensive when contracted for through a commercial firm.

To determine the demand for this type of service, letters of inquiry were sent to 23 Engineer Districts and Agencies that have jurisdiction over major waterways and could use AUSE in the future. The responses indicate that the equipment might be used 60 to 100 days per year. The estimates of use are based primarily on past use. It is difficult, in some cases, to predict future use for some projects.

III. EXPLOSIVE EMBEDMENT PENETROMETER

A. Concept

The Explosive Embedment Penetrometer (EEP) provides a "physical handle" on the sediment strength at a point on the ocean floor and determines the suitability for the deployment of the XM-200/XM-50 Explosive Embedment Anchor (EEA). This is accomplished by propelling a fluked projectile into the ocean floor and measuring the penetration and the force required to extract it.

A correlation between the penetration and extraction force of the EEP and the penetration and holding power (i.e., performance) of the XM-200/XM-50 EEA, can be established and used in the future to predict the performance of the EEA.

The EEP assembly consists of cylindrical three-legged frame approximately 2½ feet tall and 1 foot in diameter, with a gun barrel mounted in the center of the legs. The shank of the projectile (penetrometer) is placed in the barrel and the projectile propelled into the ocean sediments (rock excluded) by a cartridge that is detonated automatically (Fig. 39) when the gunstand contacts the ocean floor. A hydraulic winch on the stern of a 25-foot Coast Guard Motor Surf Boat (MSB) pulls the projectile out of the sediment as a tensiometer-footage counter measures the extraction force and the penetration.

In June 1970, a contract (DAAK02-70-C-0638) was awarded to Magnavox Systems, Inc. to develop equipment to test the feasibility of the EEP concept. During a test (September 1970) in the Potomac River, it was demonstrated to be a reasonable and simple approach to the problem of assessing the sediment suitability at a specific location for the deployment of the EEA. Based on the results of that test, an additional contract (DAAK02-71-C-0274) was awarded to the Magnavox Systems, Inc. to fabricate two gunstands and 100 projectiles (penetrometers). The first 30 projectiles were delivered with 6-inch flukes, and a test program was conducted in the Chesapeake Bay mouth to determine the fluke length that would yield the optimum spread of extract forces in a wide range of sediment stiffness.

Based on the findings, the remaining 70 penetrometers were delivered to USAMERDC with a fluke length of 1-1/8 inches. Forty-five of these were designated for additional EDT by USAMERDC and the remaining 25 were reserved for the use of the Test and Evaluation Command during testing of the Multi-Leg Tanker Mooring System.

For the feasibility test (September 1970), USAMERDC purchased from Magnavox 10 penetrometers with 3-inch flukes, a hydraulic winch with deck mounting frame, and a tensiometer-footage counter. Using this equipment, Magnavox engineers fired the penetrometers into the Potomac River using a gunstand furnished by Magnavox.

The system components purchased for the feasibility test were redesigned as a result of more rigorous tests (paragraph III D).

B. Description of Equipment.

All components of the EEP are shown in Fig. 40. No modification of the 25-foot Coast Guard Motor Surf Boat is required to mount the equipment. Description and operation of the individual components follow.

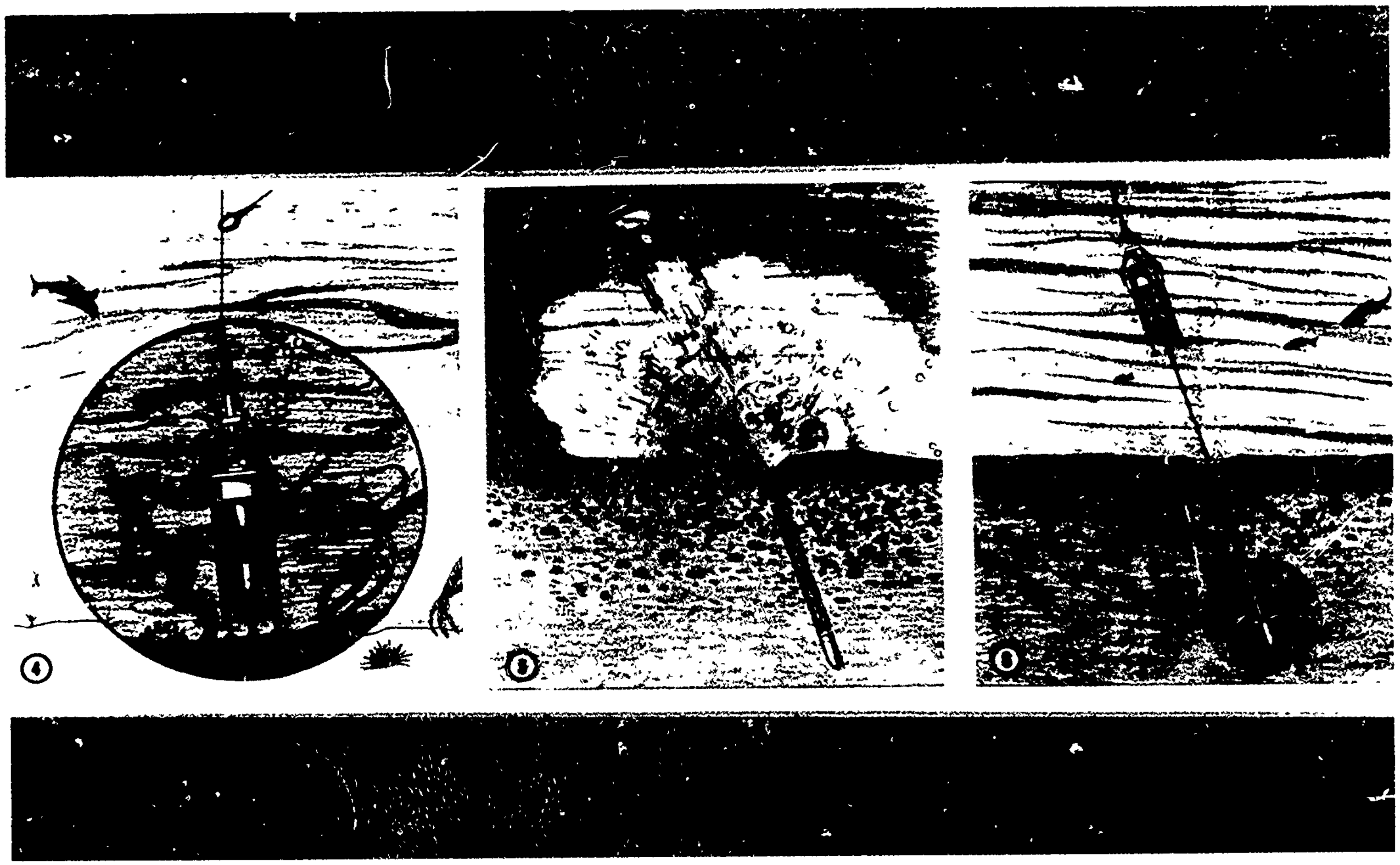
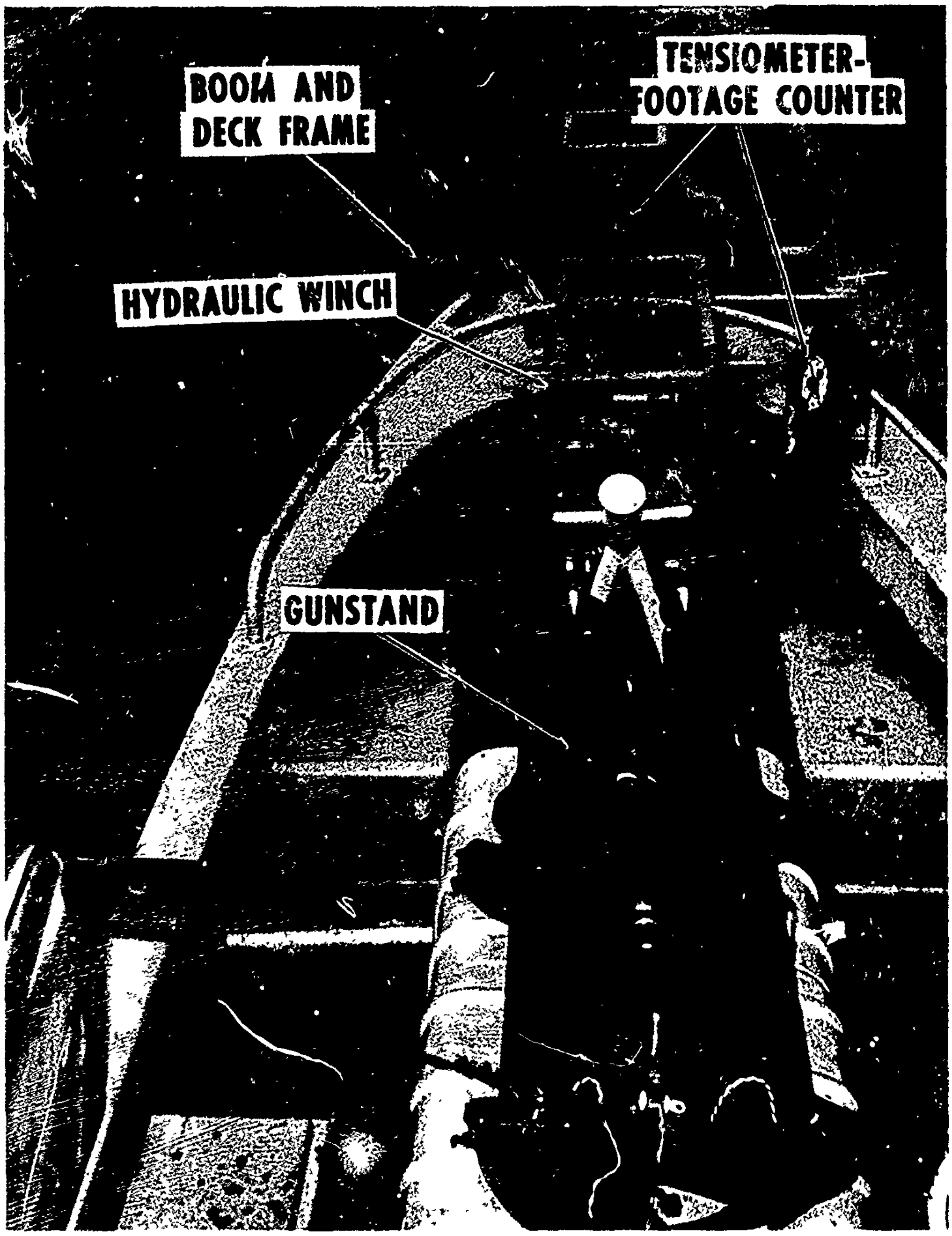


Fig. 39. Explosive embedment penetrometer concept.



V2615

Fig. 40. Explosive embedment penetrometer configuration.

1. **Gunstand.**

a. **Operation.** The gunstand (Fig. 41) is a three-legged cylindrical frame that transports to the ocean floor the penetrometer projectile and the mechanisms necessary to propel it into the sediments. When one of its legs contacts the ocean floor, it displaces a triangular trigger plate on the top end of the gunstand. As this plate moves, it trips the trigger lever on the mechanical firing mechanism, detonating the propellant cartridge in the upper end of the barrel. The shank of the penetrometer projectile is inserted in the lower end of the barrel and held in place by a shear screw. Upon detonation, the shear screw fails and the projectile is propelled into the ocean bottom.

A 35-foot serve cable connects the projectile to the gunstand. The cable is coiled into a cable pack and is pulled out as the projectile penetrates the ocean floor. The serve cable is connected to the gunstand through a shear pin. If the projectile cannot be extracted from the ocean floor, the shear pin fails and the gunstand is retrieved.

b. **Basic Parts.** The three basic parts of the gunstand are:

(1) **Legs.** The legs have disc pads on the ends to spread the weight of the gunstand on contact with the soft ocean floor and create enough force to trigger the firing mechanism. The upper ends of the legs terminate in the triangular trigger plate. They are spring biased to hold them down and away from the trigger lever. Vertical travel of the legs is restricted by collars which keep the trigger plate from pushing the trigger lever further than necessary and damaging the firing mechanism.

Leg guards run the length of the gunstand and protect the legs from rough handling during deployment and retrieval.

C-ring reinforcements connect the legs at two points. The reinforcement rings resist the spreading force on the legs that is created by the muzzle blast. The upper reinforcement ring is adjacent to the muzzle and will not itself be subjected to muzzle blast. The lower ring connects the lower ends of the legs.

(2) **Head.** The head is fabricated of welded aluminum sections with a steel insert at the center into which the firing mechanism and barrel are placed. The hydrostatic lock is also mounted on the head.

(3) **Yoke.** The lifting yoke transmits the load from the gunstand head to the hydraulic winch cable. Mounted on the yoke is the lifting/retrieval device, which is used to move the gunstand from under the boom to alongside the MSB, where it can be more easily pulled from the water.

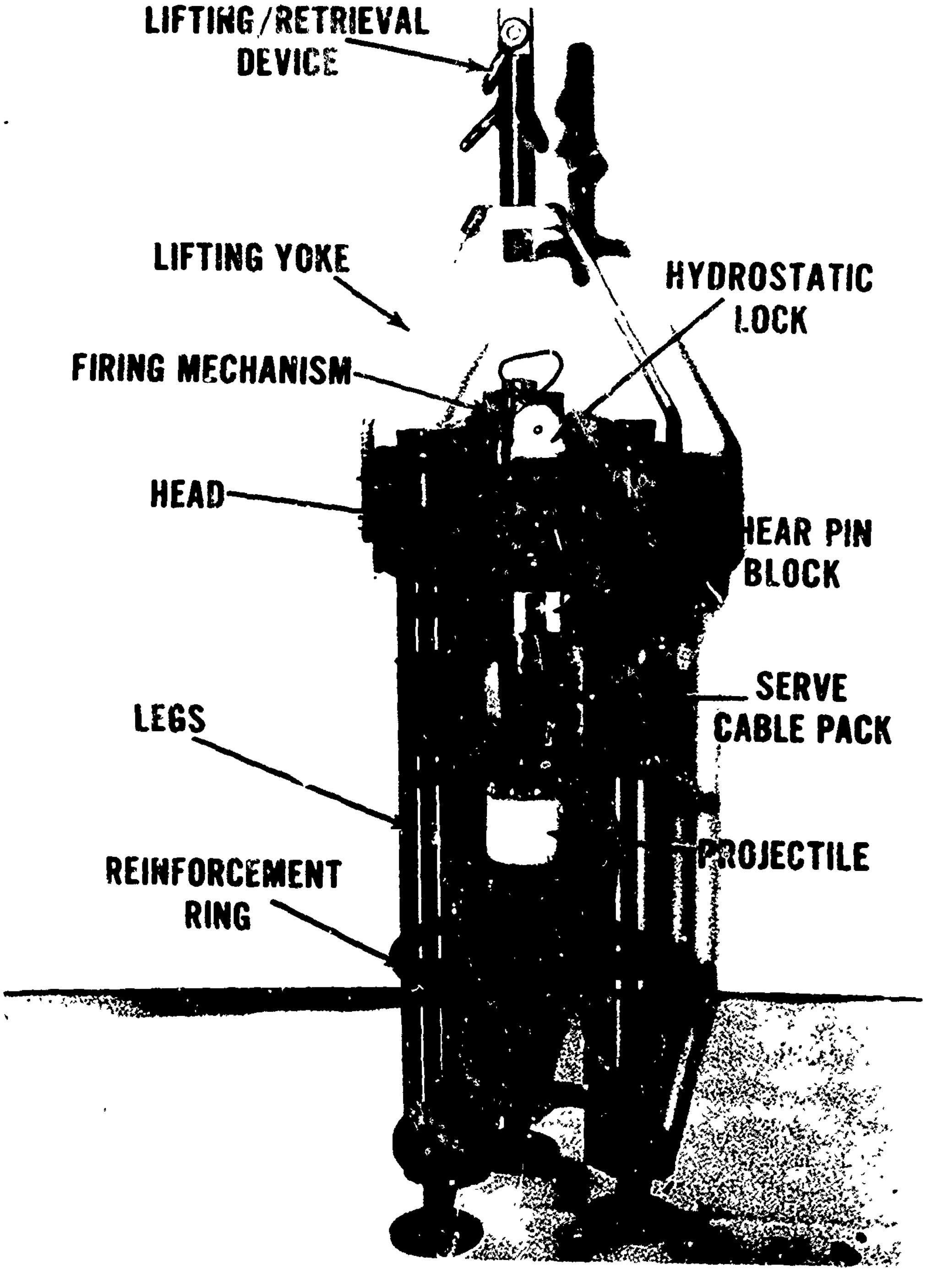


Fig. 41. Gunstand.

c. **Specifications.**

Weight	80 pounds (in air. loaded)
Height	52 inches (including lifting yoke)
Diameter	12 inches
Primary Material	6061-T6 aluminum

d. **Service Rack and Shipping Chest.** The service rack is placed over the MSB engine housing and provides a place to service and load the gunstand before a firing. Fixtures are provided to secure the firing mechanism and barrels to the rack.

The legs can be removed from the service rack so that it can be placed in the shipping chest.

e. **Acceleration.** Upon detonation, the EEP is subjected to an acceleration load of 700 times the force of gravity. The recoil of the gunstand is 1½ feet in water.

f. **Gunstand Modifications.** During the July 1971 tests, the following deficiencies were noted and the appropriate design revisions were implemented.

(1) The rectangular C-ring reinforcements were bent by muzzle blast. While the section modulus resisting the spreading of the legs was great, the perpendicular section modulus resisting bending by the muzzle blast was small.

To correct the deficiency, the rectangular C-rings were replaced by a C-ring of ¾-inch diameter 6061-T6 aluminum alloy round stock.

(2) The rectangular leg guards were secured with screws. The spreading force of the muzzle blast caused the screws to fail and left the leg guards permanently bent outward.

The leg guards were replaced by ½-inch-diameter 6061-T6 aluminum alloy round stock welded to the legs and head at all points of contact.

2. **Barrel.** The configuration of the barrel is shown in Fig. 42. The propellant cartridge is inserted into the projectile chamber (large end) which has a 0.012-inch per inch taper to facilitate the removal of an expended cartridge.

A threaded hole is provided in the barrel so that a shear screw can be passed through the barrel into a hole in the projectile shank to secure the projectile in the barrel. Upon detonation, the shear screw fails and the projectile is propelled out of the barrel.

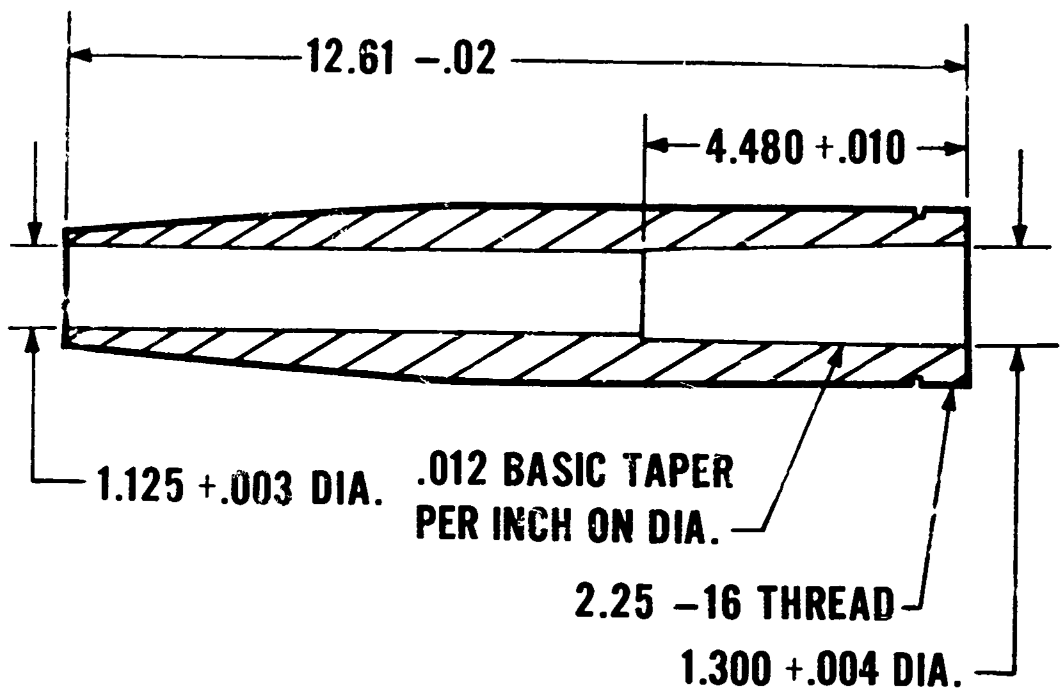


Fig. 42. Barrel.

The maximum pressure developed in the barrel during detonation is approximately 52,000 psi. A typical pressure time curve is shown in Fig. 43.

3. **Firing Mechanism.** The firing mechanism detonates the propellant cartridge by impinging a firing pin on the cartridge primer. It is threaded into the breech of the gunstand and acts as a breech block. As the firing mechanism is tightened, the O-ring (Fig. 44) is compressed against the cartridge to form a watertight seal between the firing pin and cartridge primer.

The firing mechanism is manually armed by pulling the cocking bail (Fig. 44) and raising the trigger lever. It is automatically made safe by the hydrostatic safety, which intercepts the firing mechanism linkage. The hydrostatic safety becomes passive at a depth of 20 feet, and the mechanism will initiate detonation when approximately 30 pounds is applied to any or all of the legs.

a. **Prefiring Checks.** The following two checks should be made each time the firing mechanism is armed or immediately before threading the mechanism into the breech:

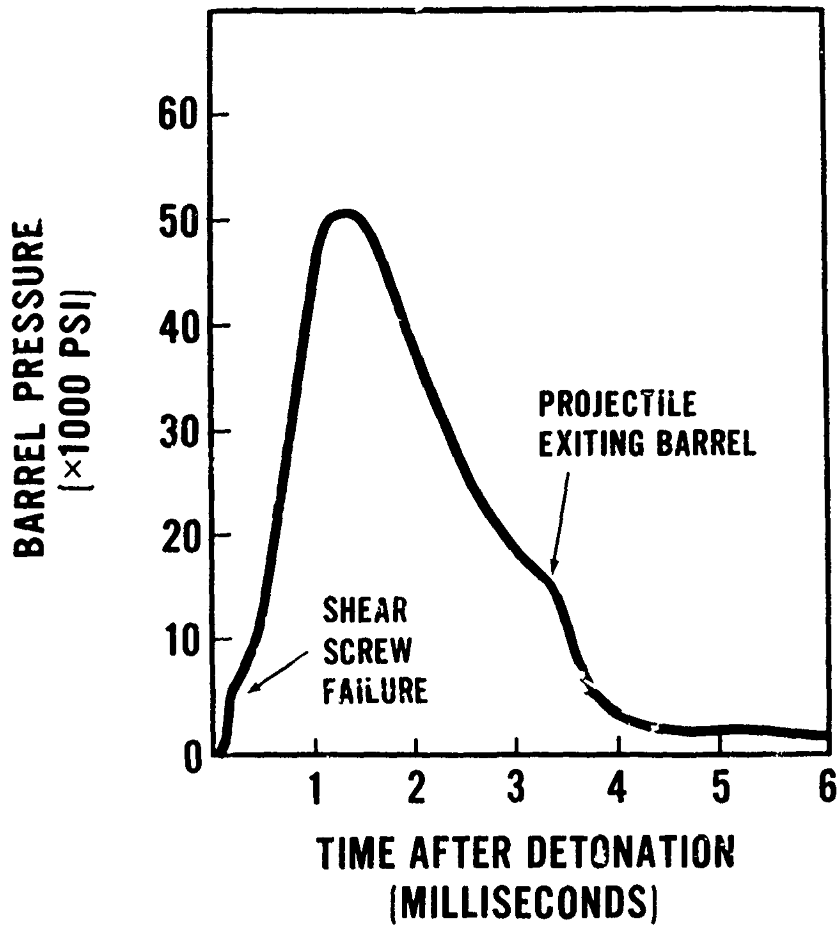


Fig. 43. Chamber pressure-time curve.

(1) Push on the trigger lever in an attempt to actuate the mechanism. It should not fire.

(2) Inspect the hydrostatic safety by touch or sight to insure that it is extended, and therefore, in the safe position.

b. **Precautionary Handling.** When the firing mechanism is not in use, it *must* be cocked. This extends the hydrostatic safety to the full length of the chamber, thus sealing it and protecting the inner surfaces from corrosion. Extensive exposure to the marine environment or airborne particles may corrode those surfaces and cause the hydrostatic safety to stick.

The firing pin hole is the only point where water can enter the body of the firing mechanism. Care must be taken to insure that water does not enter through

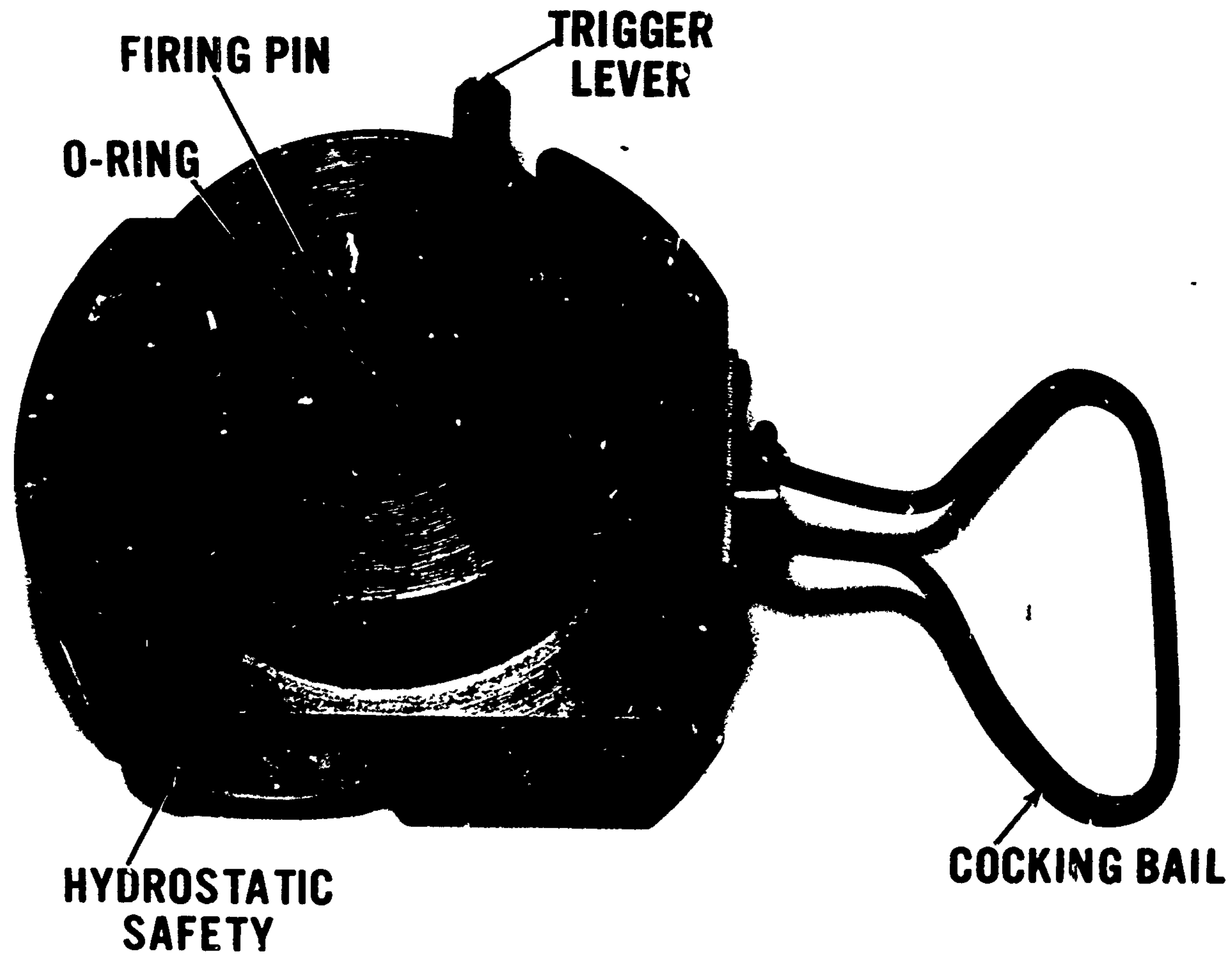


Fig. 44. Firing mechanism.

that hole when the firing mechanism is not in use. When removing it from the gunstand after a shot, immediately rotate it so that the firing pin points down and place it in the space provided in the gunstand servicing rack.

4. **Hydrostatic Lock.** The hydrostatic lock restrains the trigger plate and prevents a sudden jolt on the legs from being transmitted to the firing mechanism safety. It is set to become passive at a depth slightly less than the firing mechanism safety.

The hydrostatic lock is a cylinder within which a spring biased piston moves. As the pressure increases with depth, the piston is forced back into the cylinder against a spring and trapped air. At a predetermined depth, the piston will be clear of the trigger plate and the gunstand will be ready to fire on contact.

A screw in the cylinder can be removed to equalize the internal and external pressure to adjust the position of the piston.

5. **Penetrometer Projectile and Serve Cable.**

a. **Projectile.** The penetrometer projectile is shown in Fig 45. It has four hinged flukes that are held back for firing by a styrofoam ring. The shank fits into the barrel and is secured by a shear screw. Tests in July 1971 showed that 1-1/8-inch flukes would give the best correlation with the holding power of the XM-200/XM-50 EEA. Leaf springs placed between the shank and the fluke assist in opening the fluke when keying is initiated.

Specifications are as follows:

Weight	6 pounds
Length	18.375
Diameter of head	1.5 inches
Diameter of shank	1.125 inches

b. **Serve Cable.** The serve cable is coiled in a figure-8 fashion into a sheet metal pack. The free end of the serve cable is left bare and a swaged eye applied just before use of the penetrometer. This is done so that the serve cable can be shortened for specific situations. For example, if the EEP is to be fired in 25 feet of water at a location where compact sand is expected to be found, the serve cable should be shortened. In such a situation, penetration of 6 to 12 feet is expected, and it is conceivable that with a 35-foot serve cable, the gunstand could reach the surface before the projectile is extracted or the shear pin fails.

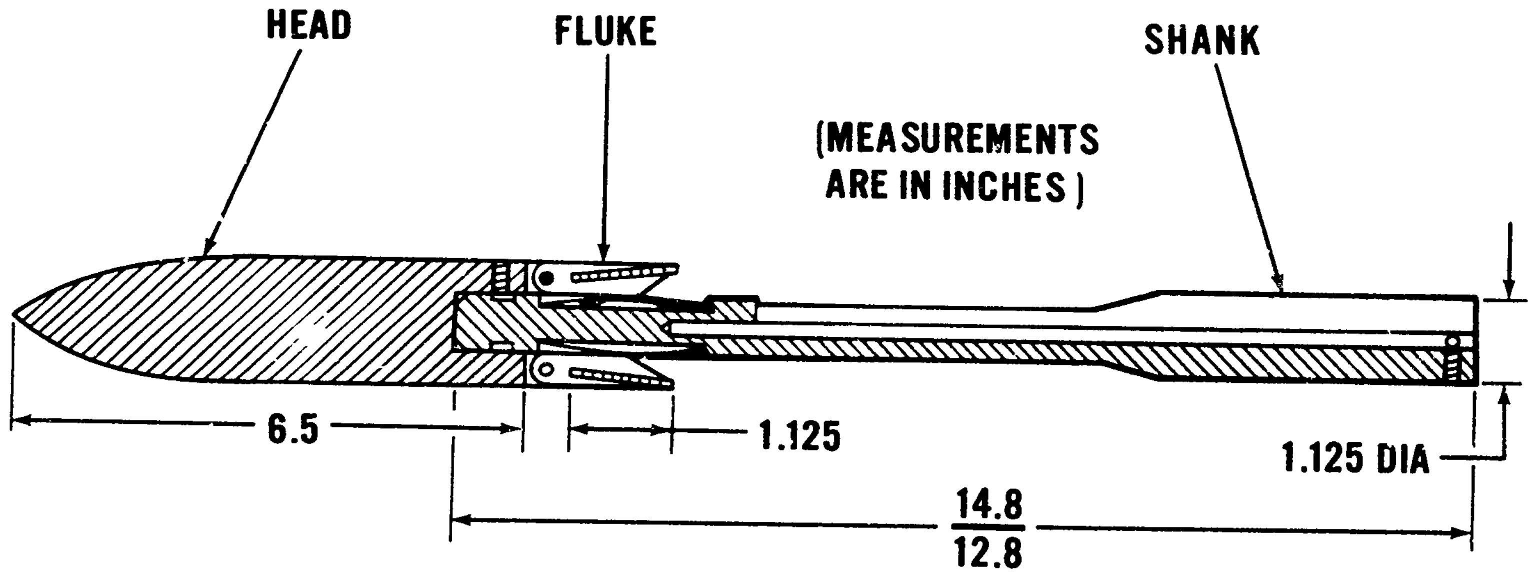


Fig. 45. Projectile.

The serve cable is attached to the projectile by a swaged cylinder. A slot in the shank allows the swaged cylinder to slide from the end of the shank toward the head to permit a portion of the shank to be inserted into the barrel. The fitting returns to the rear of the slot as the shank exits the barrel.

6. **Shear Pin.** The shear pin is designed as the weak link in the EEP. If the projectile becomes lodged in the ocean bottom and the extraction force reaches 1500 pounds ± 100 pounds, the shear pin, connecting the serve cable to the gunstand, fails and the gunstand is retrieved. The 1500-pound force was determined to be the maximum load that could safely be placed on the stern of the MSB in a Sea State Two. The shear pin is placed in a fixture on the lower side of the gunstand head.

Specifications are as follows:

Material	Half-hard Comp. 22 Brass.
Hardness	Rockwell B68-B70
Diameter	0.1410 to 0.1412
Length	1¾ inches

7. **Propellant Cartridge.** The propellant cartridge (Fig. 46) is a percussion-detonated device containing 600 grains of propellant. An interim classification of Class B, Explosive Power Device has been assigned by the Federal Bureau of Explosives Laboratory, Edison, New Jersey.

a. **Specifications.**

Length	4.613 inches with a 0.012-inch per inch taper
Diameter	1.25 inches
Propellant Components:	
Hercules No. 2400	30 grains
Hercules HPC-87	500 grains
DuPont IMR 3031	70 grains
Federal Primer No. 215	

b. **Explosive Classification Tests.** The interim classification was drawn from guidelines published in the Code of Federal Regulations, Title 46, para. 146.20-200. A test is planned to submit six cartridges to the Bureau of Explosives Laboratory for final classification. At that time, it will be requested that the cartridge be classified Class C.

This test will be funded jointly by USAMERDC and the U. S. Coast Guard.

c. **Transportation Vibration Test.** A test is planned to determine the effect of transportation vibration on the ballistic characteristics of the propellant cartridge.

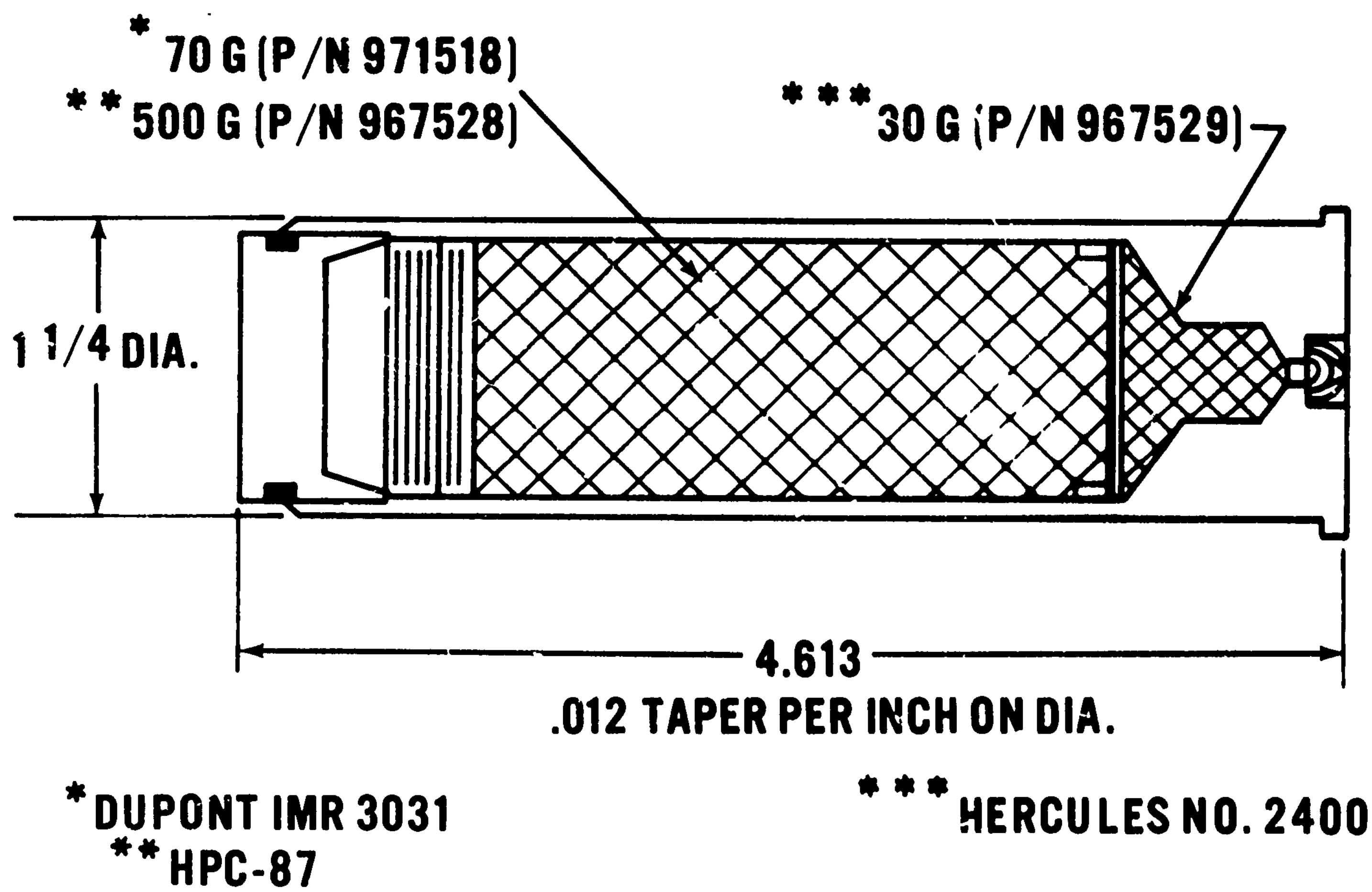


Fig. 46. Propellant cartridge.

One group of cartridges will be fired after they have been vibrated according to a schedule appearing in Materiel Test Procedure 4-2-804, 17 April 1969, subject: Laboratory Vibration Test (Aberdeen Proving Ground). A penetrometer barrel will be instrumented to record the pressure-time curves of the combustion gases.

A similar group of cartridges will be fired without being subjected to the transportation test. The pressure-time curves of both groups will be compared and the effects of vibration on the ballistic characteristics determined. This test program will be funded jointly by USAMERDC-U. S. Coast Guard.

8. **Hydraulic Winch.** The hydraulic winch is a self-contained power module capable of retrieving 2000 pounds from the ocean floor at a rate of 30 feet per minute. The winch drum contains 225 feet of 3/16-inch diameter 7x19 galvanized improved plow steel cable.

A schematic drawing of the hydraulic winch is shown in Fig. 47. The 5-horsepower 4-cycle single cylinder air-cooled engine drives the hydraulic pump which, in turn, drives the hydraulic motor. The winch drum is driven by the hydraulic motor.

A relief valve in the control valve unit can be set to bypass the hydraulic motor at any load up to 2000 pounds.

The original winch was manufactured by Hydro Products Division of Dillingham Corporation, San Diego, Calif. As discussed above, that configuration was determined to be unsatisfactory. A new winch frame (Fig. 48) was built, and the hydraulic components were mounted on it. The gasoline engine, hydraulic pump and fluid reservoir are mounted in the lower portion of the frame. The winch drum, hydraulic motor, and control valve, mounted on the top of the frame, are connected to the hydraulic pump by hoses. The winch drum is covered by a protective screen. The screen can be removed and folded for shipment.

The new winch frame (Fig. 48) is mounted on the floor at the stern of the MSB. It is fastened to the stern lifting davit and the towing bit.

a. **Hydraulic Winch Operation.** The winch is operated in the following manner:

(1) Ignition switch set to ON.

(2) Control valve lever placed to NEUTRAL position.

(3) Choke is pulled out.

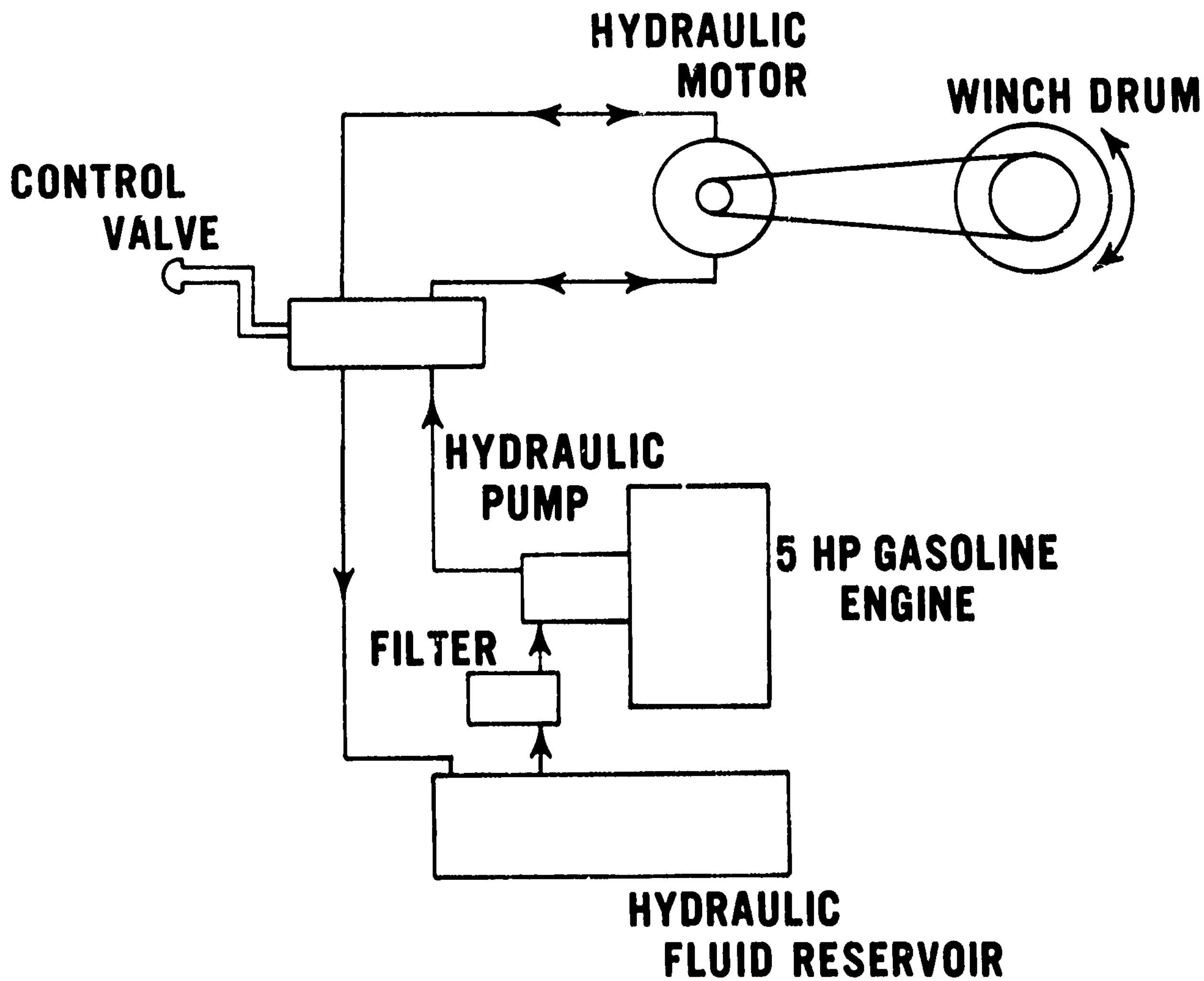
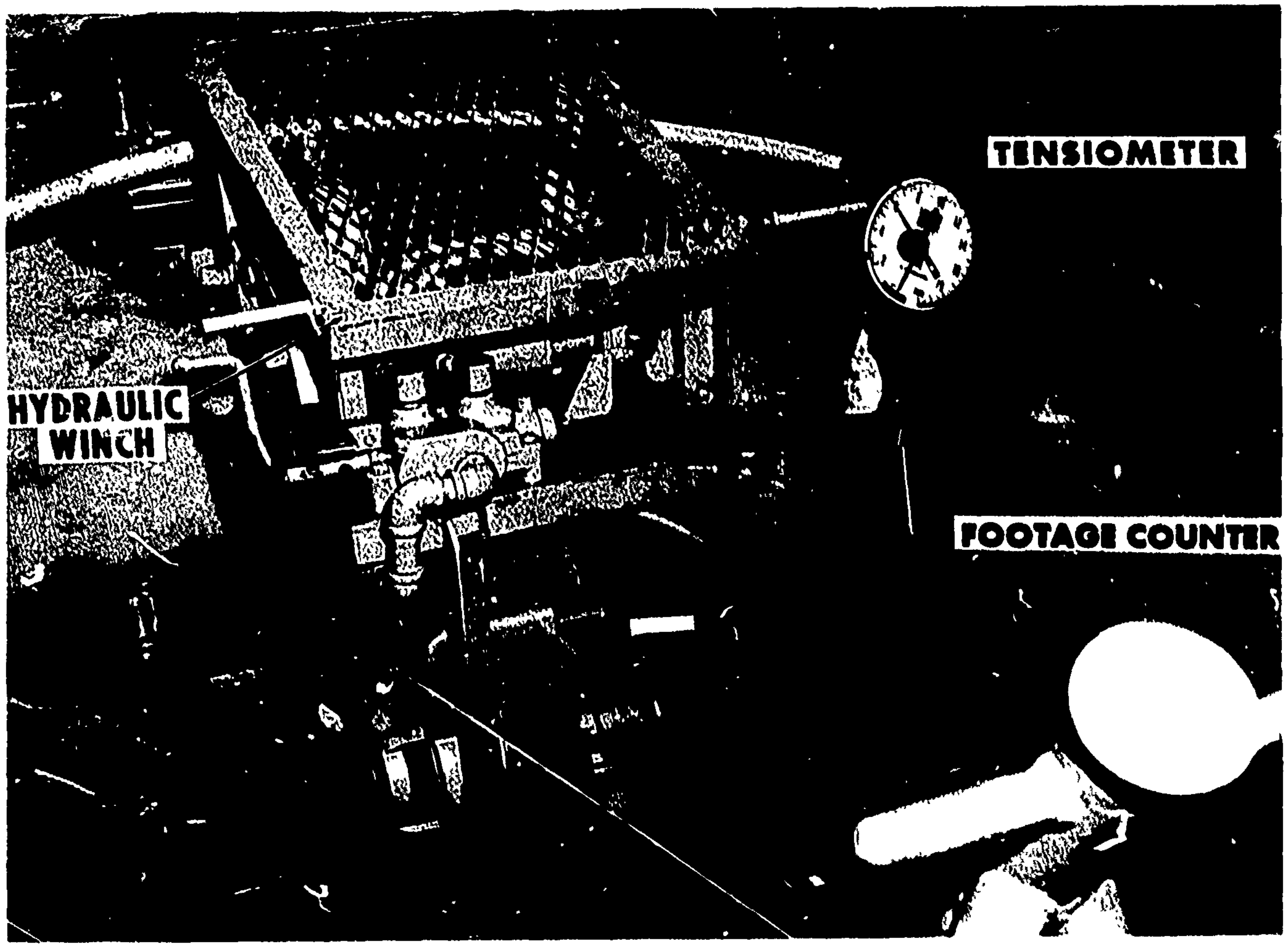


Fig. 47. Hydraulic winch schematic.



V2616

Fig. 48. Hydraulic winch.

(4) Starter cord pulled.

(5) Choke pushed in as soon as the engine starts.

(6) Clutch (left lever) is pushed forward.

(7) Control valve is moved forward or backward to move the gunstand into or out of the water.

(8) To stop the engine, ignition switch is moved to OFF position.

The hydraulic motor will hold loads up to the maximum when the control valve is in the neutral position, so the brake (right lever) is rarely used.

b. Specifications.

Weight	340 pounds
Width	15.5 inches
Height	43.5 (including guard, power winch)
Depth	17.8 inches

9. **Tensiometer-Footage Counter.** The tensiometer-footage counter (Martin-Decker UD8M Dyne-Line Tensiometer) measures the force required to extract the projectile from the ocean floor, and measures the penetration of the projectile into the ocean floor.

The tensiometer is the running-line type and consists of a three-sheaved element, a dial indicator, and a hydraulic hose connecting the two. The element is placed on the hydraulic winch cable and the dial indicator on the railing where the winch operator can see it.

The travel of the wire rope is measured by a footage counter that is an integral part of the tensiometer element. The rotation of one sheave is transmitted to the counter (mounted with the tensiometer dial) by a flexible cable.

The footage counter is designed for operation with loads of between 200 and 2000 pounds. During an EEP test, it must measure footage with only the weight of the gunstand (approximately 60 pounds in water) on the cable. Slippage can occur, and a fourth sheave was added to the end of the element in an attempt to increase the friction force between the wire rope and sheave. This was moderately successful, so the counter sheave was redesigned to grip the cable. Although this type of tensiometer has the advantage of being simple in design and requires no outside power, the inclusion of air in

the line can cause it to read as much as 50 percent low. (See Test Section.) Purging the line of air appears to be simple, but it is a tedious procedure in actuality.

It is recommended that a small in-line tensiometer be made a part of the EEP. The running-line tensiometer could be easily checked with the in-line tensiometer if suspicions arise as to its accuracy.

The tensiometer element is mounted in a gimbal on the stern deck (Fig. 49) of the MSB. This arrangement allows the tensiometer to follow the gunstand cable as it moves across the winch drum, but prevents motion parallel to the axis of the MSB.

10. **Deck Frame and Boom.**

a. **Boom.** The boom is the triangular frame placed over the transom of the MSB through which the wire rope passes (Fig. 50). The purpose of the boom is to keep the moment arm of the wire rope low so that the MSB will not capsize under a side load.

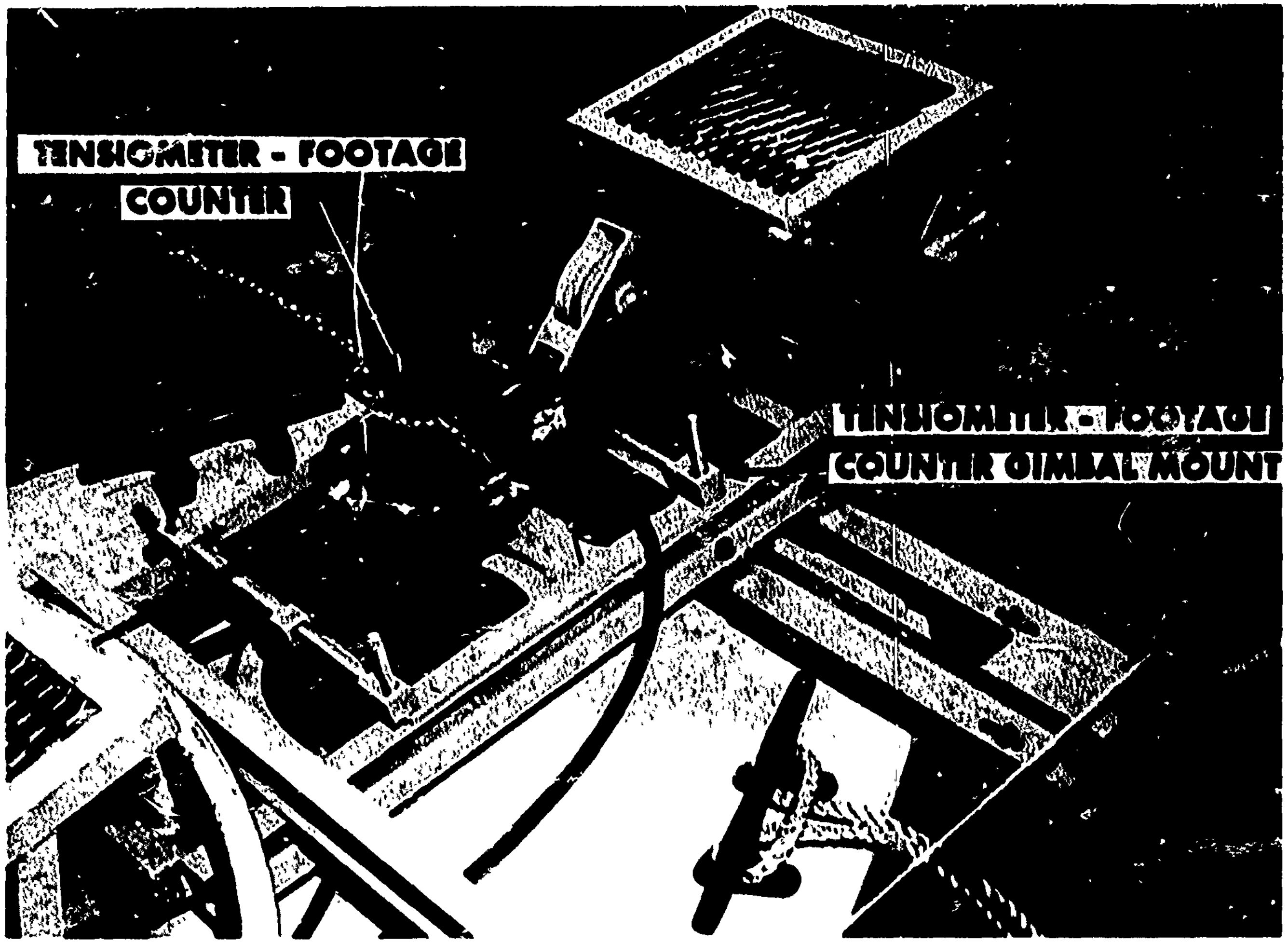
The boom is secured to the gunwale by bolts. Four of the bolts securing the rubber bumper on the side of the MSB are removed and longer bolts are passed through the side and bumper. This arrangement requires no modification to he MSB.

A handwinch pulls the boom out of the water onto the stern deck so that the wire rope is out of the water while the MSB is underway. The wire rope has caught in the propeller left in the water while the MSB was in use.

b. **Deck Frame.** The deck frame supports the tensiometer gimbal mount (Fig. 49) and the roller over which the wire rope passed between the hydraulic winch and the gunstand. The deck frame is bolted to the boom and the stern lifting davit. The boom retractor winch is mounted on the deck frame.

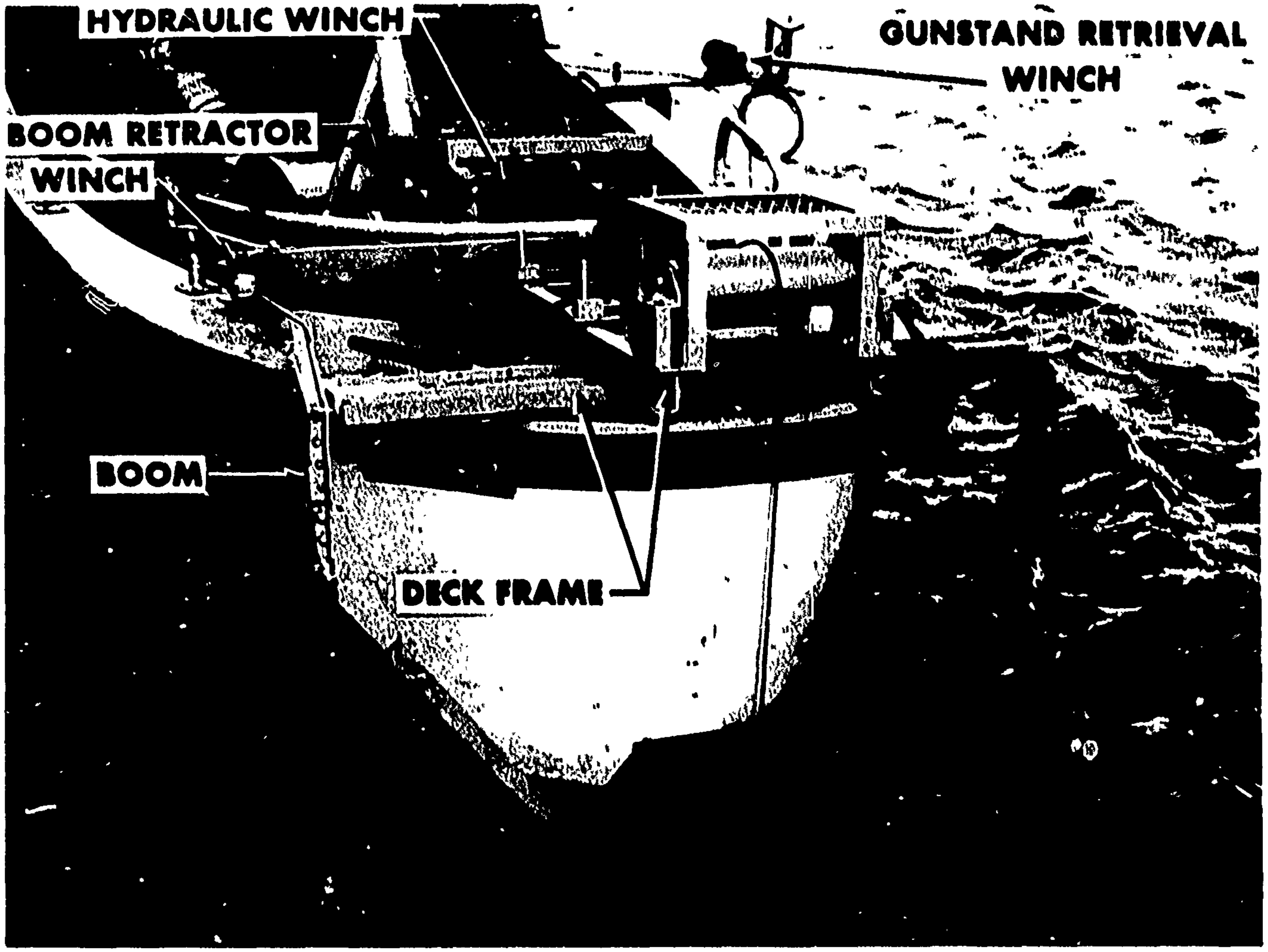
An expanded metal screen covers the roller to provide protection for the crew in the event of a wire rope failure. The screen can be removed and folded for shipping.

11. **Retrieval Device.** The retrieval device (Fig. 11) consists of a gunwale-mounted bracket, a handwinch, and ring. This device is used to move the gunstand from under the boom to the side of the MSB where it is lifted over the gunwales and placed on the service rack. The use of the Retrieval Device is discussed in paragraph III C.



V5208

Fig. 49. Tensiometer—footage counter.



V5210

Fig. 50. Deck frame and boom.

12. **Maintenance.**

a. **Barrel.** After each day, the bore, shear screw hole, and threaded retainer ring must be washed in fresh water and lubricated thoroughly. Corrosion accumulation on these surfaces reduces the tolerance to such an extent that the projectile shank will not slide into the bore and the shear screw will not turn easily in the threads. A bore cleaning rod is provided for cleaning the barrel before use.

b. **Firing Mechanism.** The water must *never* be allowed to run down through the firing pin hole into the interior of the firing mechanism.

After use, the mechanism should be wiped dry and cocked. When cocked, the hydrostatic safety is pushed out to the end of its chamber. Since the chamber is then sealed off, its surfaces will be protected from dirt and corrosion. The opening of the hydrostatic safety should be generously lubricated with a silicon grease, such as Dow Corning DC-55M or an equivalent (conforming to MIL SPEC G-4343, such as FSN 9150-273-8633. The O-ring should be replaced if it is scored.

c. **Hydrostatic Lock.** The hydrostatic lock should be wiped dry and the piston lubricated with silicon grease. The piston shoulder should be even with the outer edge of the cylinder to avoid corrosion on moving surfaces. The position of the piston can be changed by adjusting the air pressure in the cylinder by removing the screw on the back of the hydrostatic lock. Oil must *never* be used on the moving surface of the hydrostatic lock because it causes excessive friction.

C. Deployment and Data Collection

1. **EEP Deployment.** The EEP is deployed from a 25-foot Coast Guard Motor Surf Boat (MSB) in the following manner (Fig. 51):

a. The MSB is anchored at the location where the EEP is to be fired.

b. The boom is lowered over the stern using the appropriate hand winch.

c. A projectile is placed in the barrel and secured with a shear screw.

d. The barrel is placed into the breech and the retainer ring threaded on the end.

e. The serve cable eye and shear pin are placed in the shear pin block.

f. The propellant cartridge is inserted into the breech.

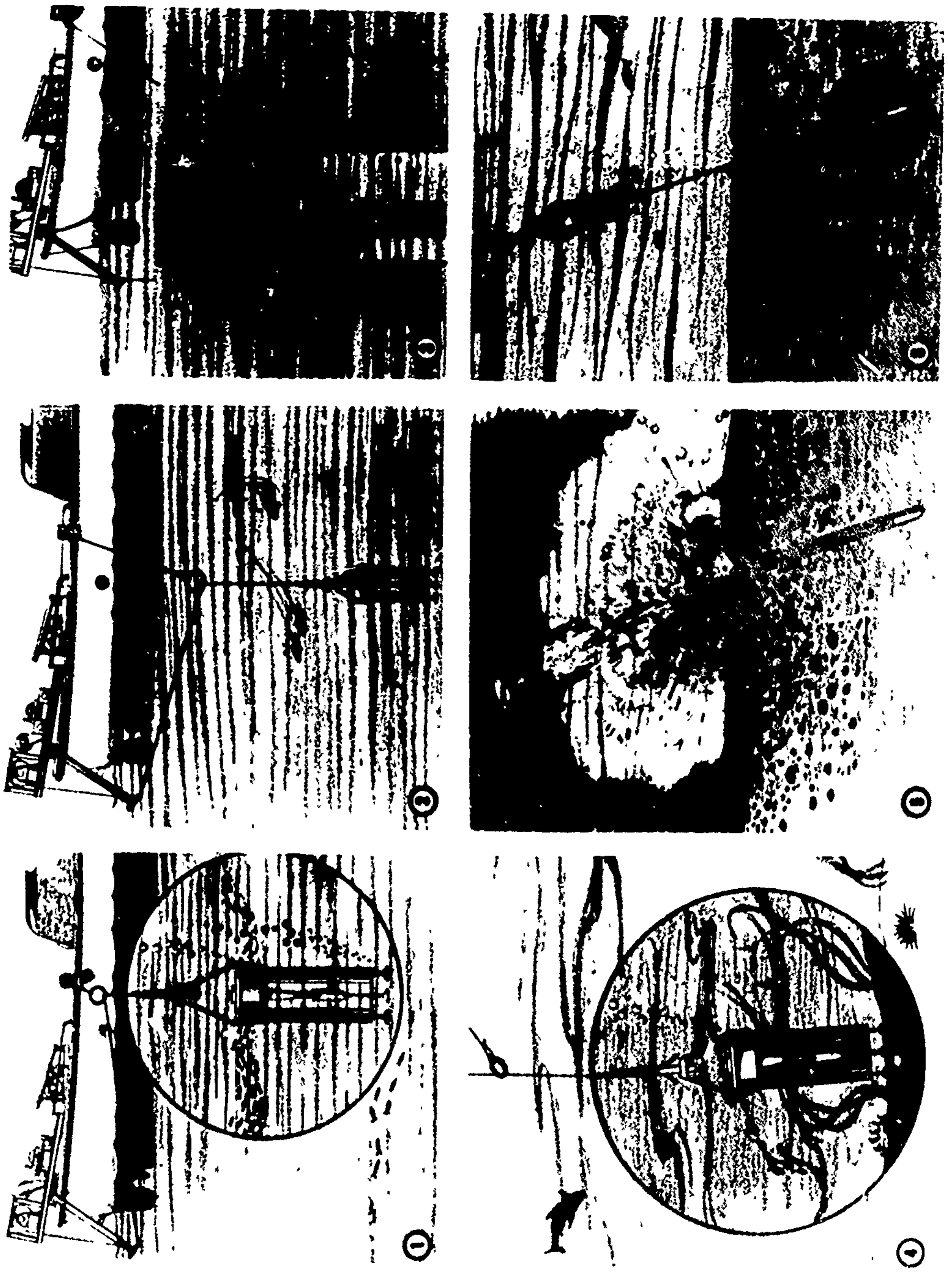


Fig. 51. Gunstand deployment and retrieval procedure.

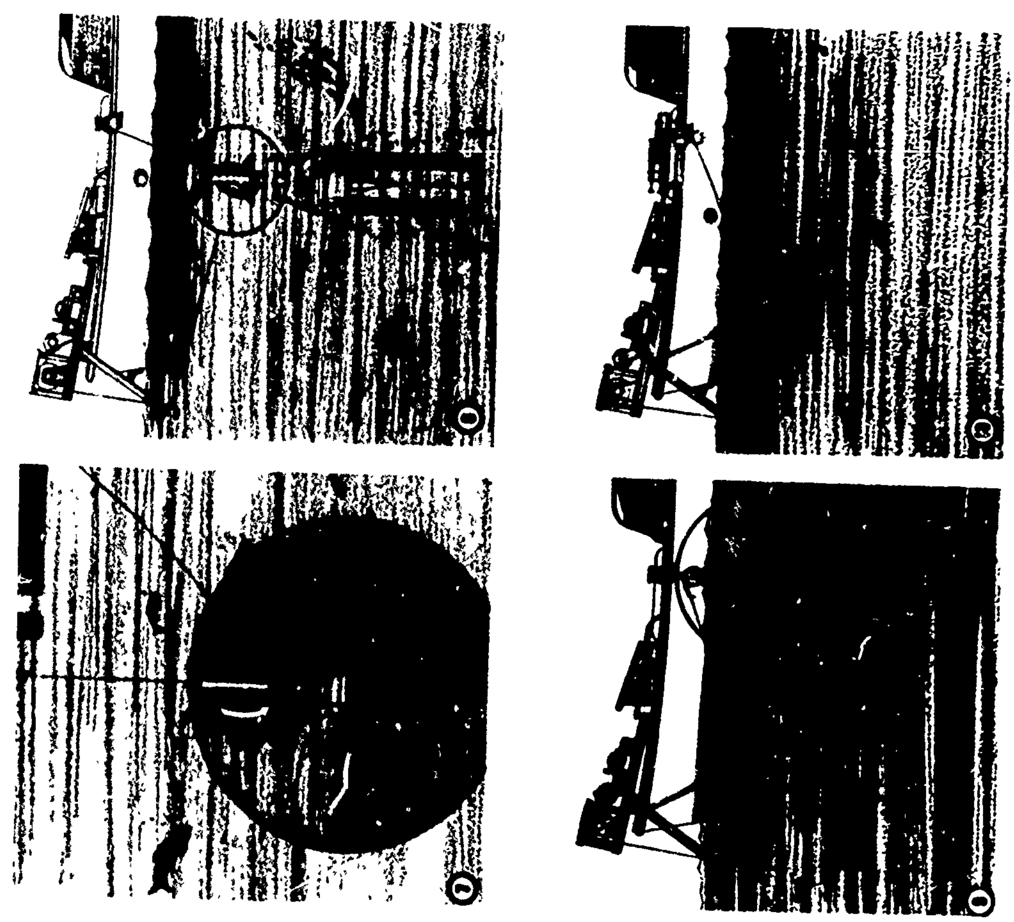


Fig. 51 (cont'd)

g. The firing mechanism is cocked by pulling on the cocking bail, then lifting the trigger lever. The safety should be checked as described in paragraph III B. The firing mechanism is threaded into breech and tightened with a wrench.

h. Hydrostatic lock is exercised on the gunstand by pressing on the pisten several times to insure that it moves freely.

i. With the hydraulic winch in the neutral position and the clutch engaged, the gunstand is put over the side of the MSB (Fig. 52) and allowed to hang just below the water's surface. The lift/retrieval device should *not* be hooked on the retrieval ring (Fig. 51, No. 1).

j. The hand winch line is paid out until the line is slack and the gunstand is hanging directly under the boom (Fig. 51, Nos. 2 and 3).

k. Using the hydraulic winch, the gunstand is lowered to the ocean floor (Fig. 51, No. 4). DO NOT drop the gunstand by disengaging both the clutch and brake and allowing the winch drum to turn freely. The center of gravity of the gunstand is near the top end: it will land on the ocean floor on its side.

l. The winch drum should be stopped immediately when the cartridge detonates.

m. The footage counter is set on zero if Method I is being used.

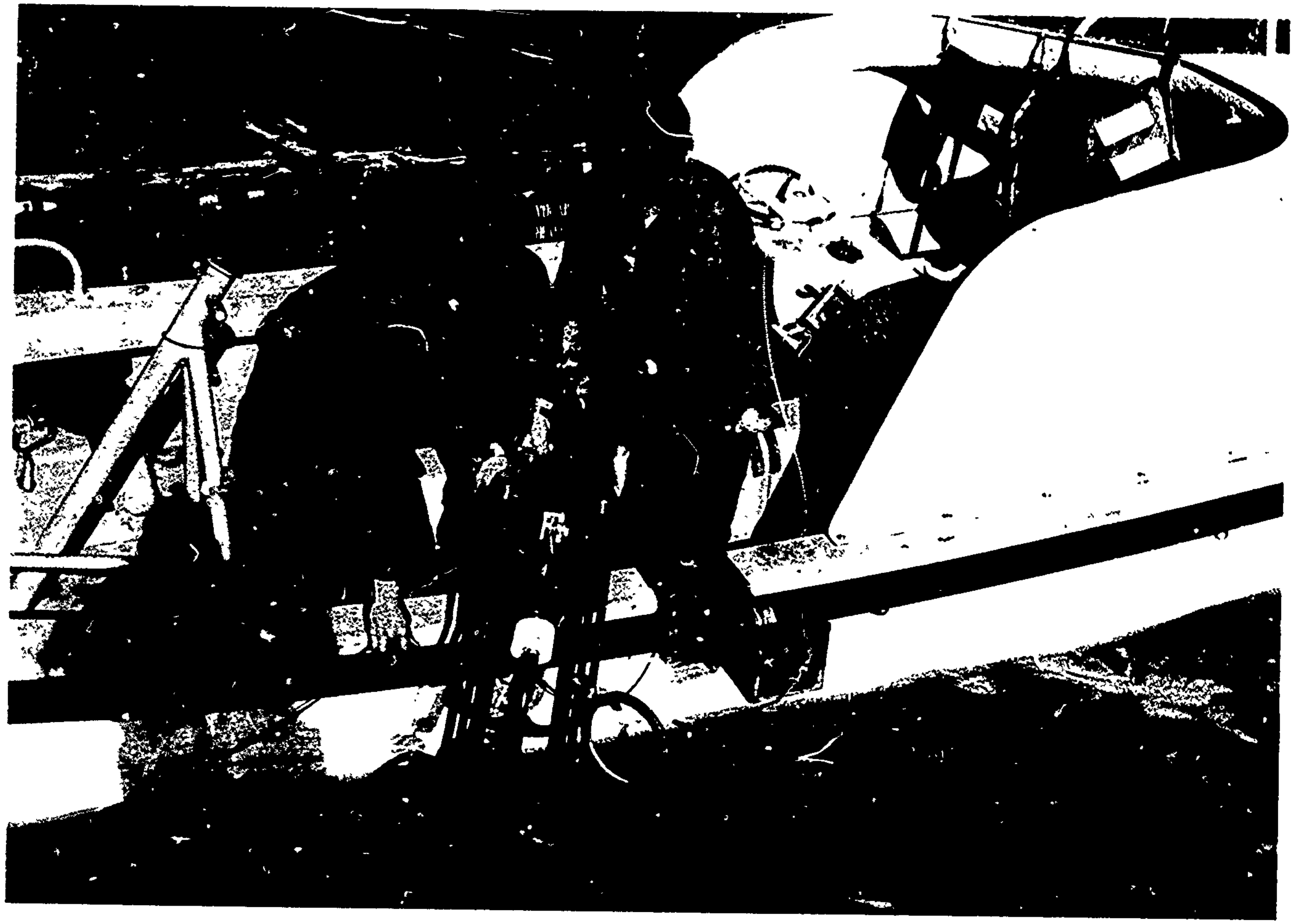
n. The tensiometer will indicate no load for several feet during the initial part of retrieval of the winch line (Fig. 51, No. 6). As soon as the tensiometer needle moves abruptly and indicates a load, the footage counter reading is recorded.

o. Continue retrieving the gunstand, noting the predominant loads and the depths over which they prevail. If the shear pin fails, the footage counter reading should be recorded.

p. When the projectile is extracted from the floor, the tensiometer reading will drop to near zero abruptly and the footage counter recording (Fig. 51, No. 7) should be recorded.

q. When the mark on the wire rope passes over the roller on the stern deck, the winch drum is stopped.

r. Force is exerted on the retrieval hand winch line to insure that the ring is caught on a prong of the lifting retrieval device. The hydraulic winch line is slowly



T14483

Fig. 52. Moving the gunstand over the side.

let out while the retrieval hand winch is taken in. The gunstand will be pulled from under the boom to the side of the MSB (Fig. 51. Nos. 7 and 8).

s. With sufficient slack in the hydraulic winch line, the gunstand is pulled from the water and placed in the service rack (Fig. 51, No. 10).

2. **Failure of EEP to Fire.** If the EEP is deployed over a very soft bottom, it is possible that the gunstand may contact the bottom and lie on its side without detonating. This could be because, in soft bottom, sufficient force is not applied to the legs by the sediment because the sediment gives way rather than resist the weight of the gunstand. This condition is compounded by a strong current that causes the gunstand to approach the bottom at an angle.

If the gunstand does not fire (i.e., detonation is not heard, but the wire rope becomes slack), the gunstand should be lifted 4 to 6 feet above the ocean floor and dropped in the following manner:

a. Lift the gunstand 4 to 6 feet above the ocean floor.

b. Set the winch drum brake.

c. Disengage the clutch.

d. Disengage the brake and allow gunstand to fall to the ocean floor.

3. **Results.**

a. **Extraction Forces.** The extraction force read from the tensiometer dial during the penetrometer test can be used directly to determine the advisability of the development of the XM-200, XM-50 EEA (paragraph XV). If the tensiometer was checked with the in-line tensiometer and a corrective curve established, it should be applied to the extraction force before entering the correlation table (paragraph III E).

b. **Penetration.** The penetration of the projectile can be measured in two ways which can then be checked against each other.

(1) **Nomenclature.**

R_1 = footage counter reading at first indication of load.

R_2 = footage counter reading at termination of load.

R' = footage counter reading at interface.

H_1 = distance from bottom of gunstand to shear pin block.

C = serve cable length

P = penetration of EEP projectile into ocean floor.

ℓ = depth of sub-bottom layers.

(2) Method I.

(a) The procedure for determining the penetration from Method I is as follows:

1. Upon detonation, the footage counter is set to zero and gunstand retrieval commenced.

2. As soon as the tensiometer indicates an abrupt load, the footage counter reading is recorded (R_1). The abrupt increase in load indicates that the serve cable remaining in the cable pack after firing has been pulled out and that serve cable and wire rope are taut.

3. Extraction then continues and values are recorded.

(b) The penetration can be calculated as follows:

$$P = C - H_1 - R_1$$

(c) This method has the advantage that break-out is not necessary to determine the penetration.

1. Any slack in the wire rope could be interpreted as decreased penetration. This could be particularly true in deep water and high currents.

2. At light loads (just the weight of the gunstand), the wire rope may slip over the footage counter sheave. This would be interpreted as increased penetration.

3. This method requires knowledge of the serve cable length. It is shortened in some instances.

(3) **Method II.**

(a) **The penetration may be calculated as follows:**

1. After detonation, retrieval of the gunstand commences.

2. When the tensiometer needle moves abruptly from no load, footage counter is set to zero (R_1). The wire rope and serve cable are then fully extended and taut.

3. Extraction and recording of data is continued.

4. When the tensiometer dial drops to no load, the footage counter reading (R_2) is recorded. This indicates that the projectile has been extracted and is clear of the ocean floor.

(b) **The penetration is calculated as follows:**

$P = R_2 - R_1$; since $R_1 = 0$, $P = R_2$.

(c) **This method overcomes the disadvantages discussed under Method I.**

1. It cannot be used in a stiff bottom where the shear pin fails, since the footage counter reading at extraction cannot be obtained.

2. It is recommended that both methods be employed to insure that some data is collected.

(4) Method I and Method II Combined.

(a) Both methods can be used and the results compared. The footage counter must be set to zero after detonation occurs.

1. Method I: $P = C - H_1 - R_1$

2. Method II: $P = R_1 - R_2$

(b) Discussion:

1. Firing into a stiff bottom necessitates the use of Method I, since the shear pin will fail and the breakout footage counter reading

(R_2) will not be obtained. If the pin fails, however, the bottom conditions are probably suitable for the EEA.

2. Method I does determine the depth of the projectile at failure.

3. This information is useful in determining if sufficient overburden is present for the EEA.

4. Method II is best suited for soft bottoms where R_1 and R_2 can be obtained. However, both methods should be used, since it is not known whether or not the pin will fail.

c. **Depth of Sub-Bottom Layers.** The depth below the ocean floor of various sediment layers can be determined from the data collected in step o, paragraph III C. According to Method I:

$$\ell = C - H_1 - R'$$

d. **Shear Pin Failure Depth.**

(1) The depth at which the shear pin fails (ℓ_s) can be calculated by using Method I:

$$\ell_s = C - H_1 - (R')_s$$

where $(R')_s$ is the footage counter reading at shear pin failure.

(2) Method II cannot be used readily because no break-out footage counter reading (R_2) was obtained since the shear pin failed before extraction was completed.

D. Engineering Design Tests (EDT).

1. Scope. Under the terms of the contract with Magnavox, the penetrometers were to be delivered in two groups. The first group (30 projectiles) was delivered with 6-inch flukes.

a. Preliminary Tests (July 1971). During the preliminary tests, projectiles were fired into a variety of ocean bottom sediment types in an effort to determine what fluke length would produce the optimum spread of extraction force in ocean bottoms ranging from very soft to stiff.

b. **Final Tests (October 1971).** Once the final fluke length was established, the second group of penetrometers (70 projectiles) was delivered with that fluke length. The objectives of the final EDT were to fire the EEP at the same locations as the XM-200/XM-50 EEA had been fired during their development and to collect sufficient data to establish a correlation between the holding power and penetration of the EEA and the EEP. The lower limit of EEP extraction force was established by firing projectiles at locations where the core sample data indicated that the bottom was too soft for EEA use. Chesapeake Test Site 10 was found to be the most useful for this purpose.

Firings in a stiff bottom established the upper limit. EEA holding power data were used to define a stiff bottom and identify suitable test sites. The upper limit was established when the shear pin failed in a stiff bottom.

Test sites where intermediate EEA holding powers have been obtained were tested to insure that the EEP can discriminate between degrees of EEA holding powers.

2. **Test Sites.** The criteria for the selection of sites were:

a. Locations where XM-200/XM-50 EEA have been fired in the past.

b. Areas where reliable core sample data is available.

c. Adequate visual navigation.

d. Proximity to support facilities.

e. Sheltered waters.

f. Variation in sub-bottom composition within a small area.

Appendix A contains the locations and core logs for the test sites. The sites offer a wide variety of sub-bottom compositions. Rock was excluded from the test sites because the AUSE will identify these areas during an operation and they will be eliminated at the outset.

The mouth of the Chesapeake Bay in the vicinity of Norfolk, Virginia, satisfies all of the above criteria and was the scene of a majority of the testing.

During previous tests, the XM-50/XM-200 EEA was deployed at Chesapeake Sites 1-4, Key West Site 1, and Potomac Sites 2, 3.[1]

The Key West Sites were too far offshore and generally subject to sea conditions too great to allow the use of the USB with any regularity. The bottom at this area is very hard coral and is referred to as "rock" on navigation charts.

Key West Test Site 4, located in 140 feet of water 1½ miles east of Site 1, was established for this test to facilitate a deep water test of the Mooring Site Survey Equipment.

Chesapeake Test Site 3 is the location where mooring was established during the 1966 EEA EDT.[1] EEAs were to have been fired at the same point that cores were taken. This would have provided excellent correlation between holding power and sediment type. Unfortunately, strong currents caused operational difficulties and the EEAs were fired as much as 300 feet from the corresponding core site.

Core samples and AUSE records indicate that the variability of the sediment in that area is so great that correlation of the EEA performance with the nearest core sample is not reliable.

Since the ultimate goal of the test program is to correlate the EEP with the EEA performance rather than the sediment type, the marker buoys at this site were placed at the EEA location rather than the core location. Core 3 and EEA 3 were sufficiently close to allow direct comparison of the EEA and sediment data.

The core sample logs for the test sites are not uniform in engineering soils information. They were collected over a number of years by different agencies using a variety of coring devices. Qualitative judgment must be used in comparing core data from different sources.

The buoys at Chesapeake Sites 2 and 3 were furnished and placed courtesy of the U. S. Coast Guard. At all other sites except 9 and 10, navigation buoys already existed. The buoys at Key West Test Sites 1 and 4 were placed courtesy of the Boat Division, U. S. Naval Station, Key West, Florida.

3. Preliminary Engineering Design Tests (EDT)—July 1971. In July 1971, an Engineering Design Test was conducted jointly by USAMERDC and the U. S. Coast Guard Field Test and Development Center, Curtis Bay, Maryland. The EEP was

---

[1] John A. Christians and Edward P. Meisburger, "Development of Multi-Leg Mooring System, Phase A – Explosive Embedment Anchor," USAMERDC Report 1909-A, December 1967.

deployed from the MSB while the LCM-8 stood by to provide on-site support capability. The fluke lengths were shortened on the LCM-8 until the proper length was reached. It was necessary to rotate test sites several times until the fluke length yielded an extraction force commensurate with the sediment stiffness.

a. **Test Procedure.** A modular workshop was placed in the cargo deck of the LCM-8 to provide the work space and tools necessary to shorten the penetrometer flukes on site. The gunstand, penetrometers, current meter, propellant cartridges and other miscellaneous equipment were locked in the workshop overnight. The propellant cartridges were stowed under provisions of 46 CFR 146.02-16. Coordination with the Captain of the Port was accomplished through the USAMERDC Marine Field Office. Each day, the LCM-8 was anchored near the test site and the gunstand, propellant cartridges and personnel transferred to the MSB for the test. The MSB then moved to the test site and was anchored or tied to a marker buoy.

Current speed data were collected on the LCM-8 using a Marine Advisers, Inc., Model Q-8 ducted water current meter.

After the USAMERDC personnel completed testing at a site, the MSB returned to the LCM-8 and deposited the USAMERDC personnel and transported the Coast Guard personnel to conduct their tests. Based on data just collected, USAMERDC personnel could then modify fluke length in preparation for the next test.

The workshop on the LCM-8 proved a valuable asset. All equipment difficulties, with the exception of a parted weld on the EEP deck frame, could be handled on the LCM-8 without returning to the dock.

b. **Data and Results.** The EEP was fired 23 times, in waves up to 2½ feet, winds up to 20 knots, water depths of 55 feet, and current in excess of 2 knots. One complete cycle (loading, firing, retrieval) in light seas and 45 feet of water requires approximately 6 to 8 minutes.

The data collected during the test are shown in Appendix B. The results indicate that a fluke length of 1-1/8 inches would produce the desired correlation.

c. Discussion.

(1) During three extraction tests, the serve cable failed under low loads. Two shots were fired at Test Site No. 4, which is located near a wreck. Magnavox engineers indicate that bottom debris can damage the serve cable as it penetrates the ocean floor. They also described how a swage fitting failure can be distinguished from a serve cable failure:

(a) If the wire and armor were the same length at the end, the cable was damaged as it penetrated the ocean bottom and failed under the load of the hydraulic winch during the subsequent test.

(b) If the wire extended beyond the armor, the wire was pulled out of the swage fitting. The armor was removed during fabrication so that the wire will fit into the swage fitting.

(2) The EEP was deployed in currents that were strong enough to cause the LCM-8 to drag anchor and make accurate current measurements impossible. In strong currents, the gunstand was observed to descend to the ocean floor at a large angle from the vertical. There was no obvious effect on the data.

(3) On the first day of operation, the MSB was moved to Test Site No. 6. Swells of at least 4 feet developed and the MSB started back to the dock. Rough surface conditions required the MSB to slow down and stay inside the wake of the LCM-8. That condition appeared to be the safe limit of operation for the MSB with the added weight of the EEP and was well beyond the limit of comfort of the crew.

(4) The EEP was fired on all occasions with the MSB anchored or tied to a marker buoy with the bow into the sea.

(5) The sediment retrieved on the flukes of the projectile provided additional information that is useful in assessing the type of sediment present at the test site.

(6) Equipment performance was as follows:

(a) Gunstand. The gunstand functioned well during the tests. Some corrosion was noted on the hydrostatic lock and firing mechanism. That problem was later corrected by applying a more rugged, salt-water-resistant plating.

(b) Hydraulic Winch. In choppy waters, the MSB had a tendency to list under the weight of the hydraulic winch (approximately 250 pounds) on the stern deck. At cruising speed, the MSB had a strong tendency to roll and was "stern heavy." To move its weight to a lower position and diminish its effect on the handling characteristics of the MSB, the winch was later redesigned to be mounted on the floor (Fig. 48). Placing the hydraulic winch on the floor allowed the following additional modifications:

1. Moving the tensiometer element from over the stern and placing it on the stern deck to increase accessibility.

2. Rotating the boom up over the stern to remove the wire rope from the water while the MSB was underway.

(c) Tensiometer-Footage Counter. On the first day of testing, a large error was noted in the tensiometer. It indicated only 750 to 800 pounds when the shear pin failed at 1500 pounds. Using an in-line tensiometer, a calibration curve was made so that the data previously collected could be used.

At the conclusion of EDT, the tensiometer was returned to the Martin-Decker Corporation for inspection and calibration. They indicated that there were no apparent malfunctions in the tensiometer. The error may have been caused by air trapped in the line.

The instruction manual supplied by Martin-Decker was found to be of little value. The descriptions of mounting and fluid charging procedures were inadequate and the diagrams were mismarked and erroneous.

The footage counter would not work with just the weight of the gunstand (55 pounds) on it. The manufacturer stated that it was designed to operate at a minimum load of 150 to 170 pounds.

An idler wheel or fourth sheave should be used to increase the friction between the wire rope and the counting sheave.

In the original configuration, the tensiometer is hung over the stern of the MSB. When the wire rope is slack, it is not confined in the sheave, and a man must climb over the stern and place the wire rope back on the sheave.

d. Penetrometer Boom. The wire rope was drawn into the MSB propeller when the operator neglected to insure that the wire rope was clear of the propeller before getting underway. Removing the boom (and therefore the wire rope) from the water is an adequate solution. Moving the tensiometer to the deck allowed the boom to be rotated up over the stern. A hand winch is provided for that purpose.

4. Final Engineering Design Test. Following the finalization of the penetrometer fluke length, a test program was undertaken to establish a correlation between the penetration and extraction forces of the EEP and EEA. The test was conducted at the locations where data were available from previous XM-200/XM-50 EEA Engineering Design

Tests. A description of the tests and acquired data follows. The results extracted from the data are discussed in paragraph III E.

a. **Chesapeake Bay Tests—October 1971.** The procedure followed during preliminary EDT (paragraph III D) was used during the final EDT at the Chesapeake Bay test sites.

Nineteen projectiles were fired at Test Site 3 in approximately 4 hours. The MSB was tied to the marker buoy in all cases. No other test sites were used. The sea was calm, visibility excellent and the winds light. Wave heights and period are shown in Appendix C.

(1) The penetration and extraction forces of the EEP are shown in Appendix C.

(2) Before the test, considerable effort was expended in cleaning the rust from the base of the penetrometer barrel. It had corroded to the point that the shank of the projectile would not fit into the barrel. Steel wool and oil were used to remove the rust. Care must be taken to lubricate the barrel after each EDT to prevent corrosion.

The leg guards on the gunstand came loose at the bottom when the fasteners failed in three successive firings. The gunstand was modified to correct that deficiency by welding on leg guards of circular cross-sections as discussed in paragraph II B.

During the test, it was noted that the shear pins failed at loads somewhat higher than the 1500 pounds ± 100 pounds specification required by the purchase description of the contract. The USAMERDC Materials Research Support Division checked six pins for diameter and hardness and found them to be 0.1416 (within specification) and 85.5 Rockwell "B," respectively. This is in excess of the 68-70 R_B limit set by laboratory tests during the development of the equipment. The remaining shear pins were replaced by Magnavox with pins that meet the specifications.

b. **Potomac River Tests—November 1971.** Six penetrometers were fired at Potomac River Test Sites 2 and 3 (Appendix A). At Test Site 3, the U. S. Coast Guard fired two projectiles currently under development by the Field Test and Development Center.

(1) The data collected are shown in Appendix D.

(2) The first shot was over the slope on the side of the river channel and apparently struck an object, causing the serve cable to fail. Divers and side scan sonar have verified that the area is littered with trees and boulders.

The succeeding three shots were fired in the channel. It was found that the bottom was so soft that the gunstand, on occasion, would not fire when it was lowered with the winch. The procedure for firing in this condition was derived during this test and is discussed in paragraph III C.

Two penetrometers were fired in the vicinity of Buoy 54 at Site 2. Currents were visually estimated to be in excess of 3 knots. Since only visual navigation was used, approximate locations were obtained.

c. **Key West, Florida Test—February 1972.** The Key West test sites are near Middle Sambo Key, 5¼ miles offshore and 12 miles from the U. S. Navy Station (Appendix A). Weather conditions change rapidly in that area, and 2- to 4-foot seas are the normal conditions.

Seas of 4 to 8 feet were expected during the test period, and it would be unwise to traverse 12 miles of rough seas in the MSB if bad weather developed; therefore, the equipment was mounted on a 63-foot Laboratory Boat provided by the Naval Station Boat Division.

(1) The extraction and penetration values are shown in Appendix E.

(2) Four projectiles were fired at Test Site 1. The penetration of three projectiles was 4 to 5 feet, while the fourth apparently did not penetrate and was retrieved with a bent shank. One projectile penetrated 5 feet and was retrieved with the flukes closed and small pieces of hard coral trapped between the flukes and the shank. The shank was also bent (Fig. 53).

The nautical charts indicate "rock" approximately 800 yards west of Test Site 1. This area is actually hard coral. At Test Site 1, serve cable lengths of 29 feet were used in anticipation of limited water depths, as outlined in paragraph III B.

Four projectiles were fired at Test Site 4, where penetrations of 14 to 28 feet were recorded. These shots were not all in the same location because the boat dragged anchor at times during the test. Recovered projectiles had soft white sediment on the flukes. A current profile was taken at Site 4. Since the boat was dragging anchor during part of the test, the curve is not very reliable. If

V2619

Fig. 53. Explosive embedment penetrometer with bent shank.

[illegible] no wind, however, a current of 3 to 4½ knots was present in the bottom 10 feet of the water column.

Subsequent laboratory tests (paragraph III F) showed that the gun-round will assume an angle of approximately 45° from the vertical in that current.

On one occasion, the wire rope became wedged between previous wraps on the drum while the extraction test was performed. Some effort was required to pry the wire rope out with a bar.

E. Results.

The following results were abstracted from the data collected during the final EDT (Appendices C, D, and E).

1. **EEP Penetration.** The following penetration values are characteristic of various types of ocean bottom composition.

Material	EEP Penetration (Feet)
Coral	5
Sand	12
Sand (10 ft) over clay	16
Silt and clay	19
Mud	29

2. **EEP Extraction Forces.** The following values are representative of the forces required to extract the EEP projectile from various sediments.

Material	EEP Force (Pounds)
Sand	1300-1500 (Shear Pin Failure)
Clay	700-1100
Mud	Less than 500

3. **EEP Versus XM-200 EEA Penetrations.** Considerably more penetration and holding power data are available for the XM-200 EEA than for the XM-50 EEA. Consequently, the EEP was correlated to the XM-200 EEA.

The XM-200 EEA and EEP penetrations in a variety of ocean bottom compositions are shown in Fig. 54. The ratio of the penetrations of the EEP and the XM-200 EEA is not consistent. However, a useful approximation is 1:1.7 or

$$1.7\ P_{EEP} = P_{200}$$

A comparison of the XM-200 EEA EDT data with the limited quantity of XM-50 EEA EDT data shows that the penetrations of the two anchors are approximately the same.

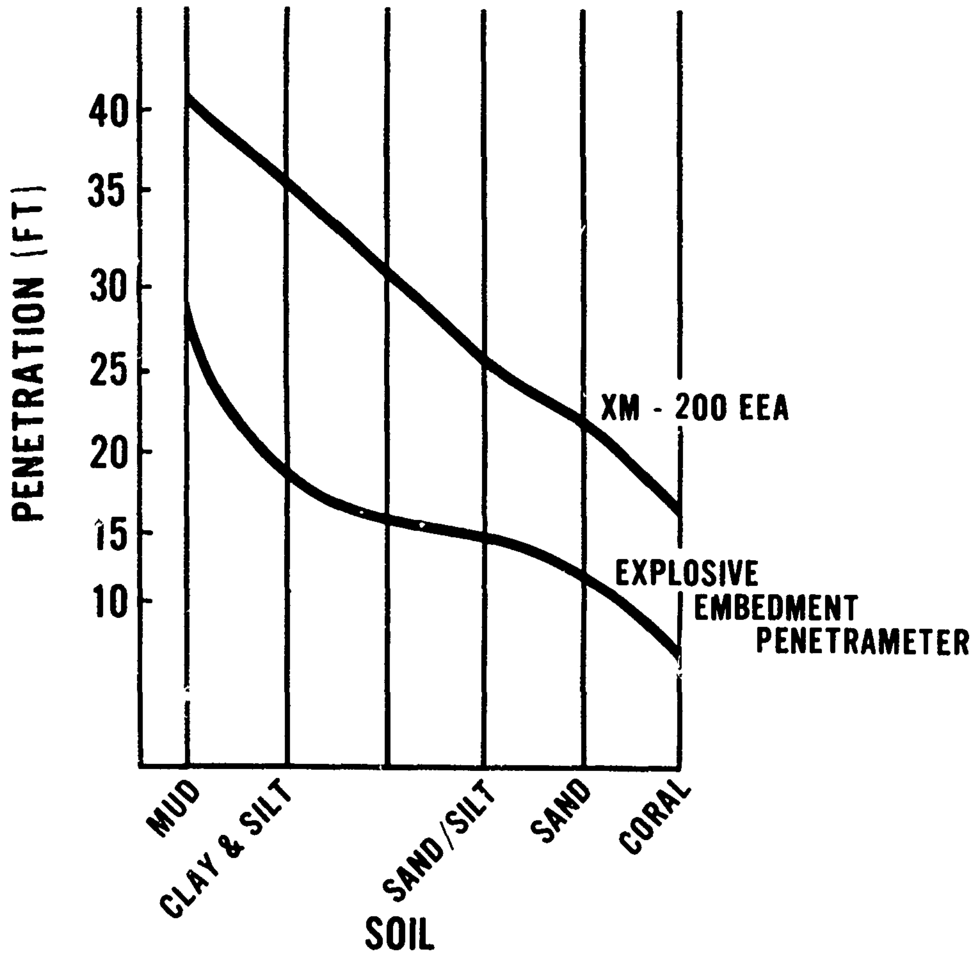


Fig. 54. Explosive embedment penetrometer and XM-200 explosive embedment anchor penetration in various ocean bottom compositions.

4. EEA Holding Power Correlation Chart.

a. The penetrations and holding powers of the XM-200 EEA have been correlated with the penetration and extraction force of the EEP and compiled in chart form (Table IV).

Table IV. Explosive Embedment Anchor Holding Power Correlation Chart

EXPLOSIVE EMBEDMENT PENETROMETER		EXPLOSIVE EMBEDMENT ANCHOR		
PENETRATION (FT)	EXTRACTION FORCE (LB)	XM - 200 HOLDING POWER	XM - 50 HOLDING POWER	HOLDING POWER RATING
10	1500	200,000	50,000	VERY GOOD 100%
	1000	150,000	37,500	75%
17	700	60,000	15,000	GOOD 74% FAIR 30%
22	400	35,000	7,000	MARGINAL
35				POOR

b. The holding power of an EEA at a location can be predicted by entering the chart on the right with either the EEP penetration or extraction force at the location. The EEA holding power and rating are read on the left. If the extraction force and penetration do not give the same results, use the one that yields the most conservative answer. The holding powers of the XM-200/XM-50 EEA have been rated as percentages of the maximum holding power.[2]

[2] H. C. Mayo, "Installing and Mooring Test of Multi-Leg Tanker Mooring System Incorporating Explosive Embedment Anchors (ET/ST, 1766)." Unpublished, U. S. Army Mobility Equipment Research and Development Center, January, 1968.

c. In some areas, stiff sediments may overlay a soft sediment. When the EEP is deployed, it may pass through the stiff sediment to the soft sediment below. When extraction is begun, readings commensurate with the soft sediment will be observed. As the projectile encounters the underside of the stiff sediment, the extraction force will increase and the shear pin may fail.

The depth of the projectile at failure (i.e., the thickness of the stiff sediment) can be calculated employing the procedure outlined in paragraph III B. A depth of as little as 12 feet will indicate that the EEA may be considered to have a fair holding power.[3]

Depth values indicating a thickness of less than 12 feet should be considered marginal and it may be advisable to test a new site or deploy two EEA's in tandem.

d. A study by Vesec[4] indicated that surge loading (i.e., a wave lifting the MSB during the extraction test) in this case would not be of great significance. Examination of the data does not indicate that this loading condition produces a disparity in the results, and no extensive testing was undertaken to establish its effects conclusively. The test sites were generally too far offshore to permit testing in rough water. In its early configuration, the hydraulic winch detracted significantly from the rough water handling characteristics of the MSB.

F. Gunstand Excursion Characteristics.

A study was undertaken to determine the contribution of ocean current to the deflection of the gunstand from the vertical and to the excursion of the gunstand from a point directly under the MSB. The above objectives were accomplished by towing the gunstand in a tank and measuring the angle of, and forces on, the end of the two cable and by using those values as boundary conditions for an equation of the current forces on the EEP wire rope.

1. **Tow Tank Test.** The construction of the gunstand is such that the mass is concentrated in the head, while the drag force due to current is concentrated predominately on the legs. Preliminary calculations and observations indicated that the effect of current on the gunstand should be investigated in detail. The test was undertaken by Hydronautics, Inc., in February 1972.

---

[3]See Christians and Meisburger, "Development of Multi-Leg Mooring System, Phase A–Explosive Embedment Anchor." Figure F-12, USAMERDC Report 1909-A, December 1967.

[4]Aleksander S. Vesec, "Breakout Resistance of Objects Embedded in Ocean Bottom," Duke University, Durham, North Carolina, May 1969.

a. **Test Procedure.** The gunstand was suspended in the tank below the carriage that traverses the length of the tank. The cable suspending the gunstand from the carriage was attached to a transducer that measures vertical and horizontal forces. The resultant of these forces is the cable tension and the ratio is the angle that the gunstand makes with the vertical.

A Nikon Motor Driven Underwater Camera was placed at mid-tank opposite a grid. As the carriage travels along the tank and the gunstand passes between the camera and grid, a photograph is taken and the angle between the gunstand and grid is measured from the photograph and used to check the results obtained from the force transducer. Carriage speeds of ½, 1, 2. 3, 4, and 4½ knots were used.

b. **Results.** Regardless of the orientation of the gunstand in still water, the current rotates it so that the closed side of the C-ring reinforcement points in the direction of motion. At slow speeds, however, the profile presented to the current may not be completely symmetric.

The horizontal and vertical components of force at the end of the cable is shown in Fig. 55. The angle that the gunstand makes with the vertical (angle between the forces in Fig. 55) is shown in Fig. 56. The angle increases linearly with current up through 3 knots. The cable tension (resultant of the force components) is shown in Fig. 57.

The angles obtained from the photograph and the transducer are compared in Fig. 58. The photographic data show that the gunstand is at a somewhat larger angle than the cable. AT 2 knots, the deviation is an insignificant 3°. Figures 59 and 60 are representative of the photographic data. They represent current velocities of 2 knots and 4 knots, respectively.

c. **Penetration Error Assessment.** The error induced in the penetration by the current acting on the gunstand is assessed by considering two extreme cases with the understanding that the common case falls between the two extremes.

If the penetrometer is fired into the bottom at an angle of incidance ϕ, the ensuing extraction test will fall between two extremes as shown in Fig. 61.

(1) **Stiff Sediment (Line A).** Determining the penetration by Method I (paragraph III C), the gunstand is raised until the serve cable is fully deployed and an increase in load is indicated. If a stiff sediment is present, it will resist the effort of the serve cable to seek a straight line between the gunstand and the penetrometer. The indicated penetration will be greater than the vertical penetration.

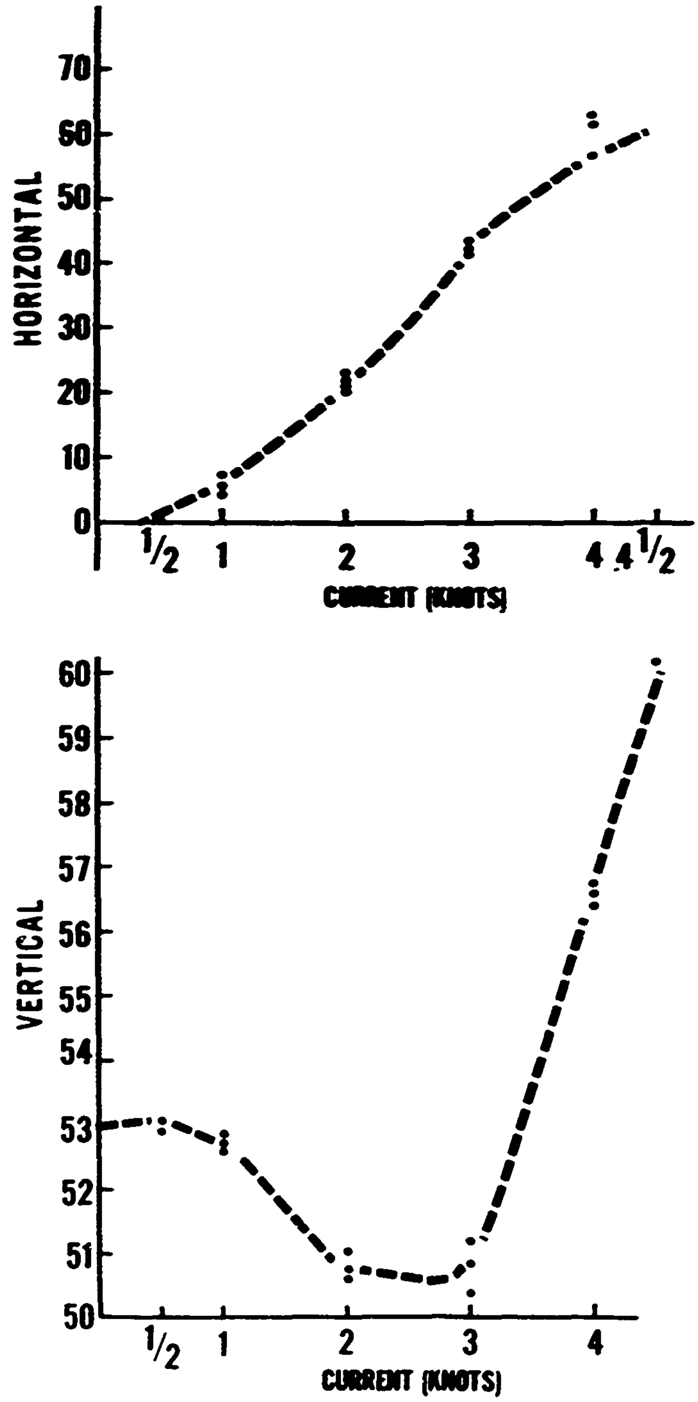


Fig. 55. Explosive embedment penetrometer force components.

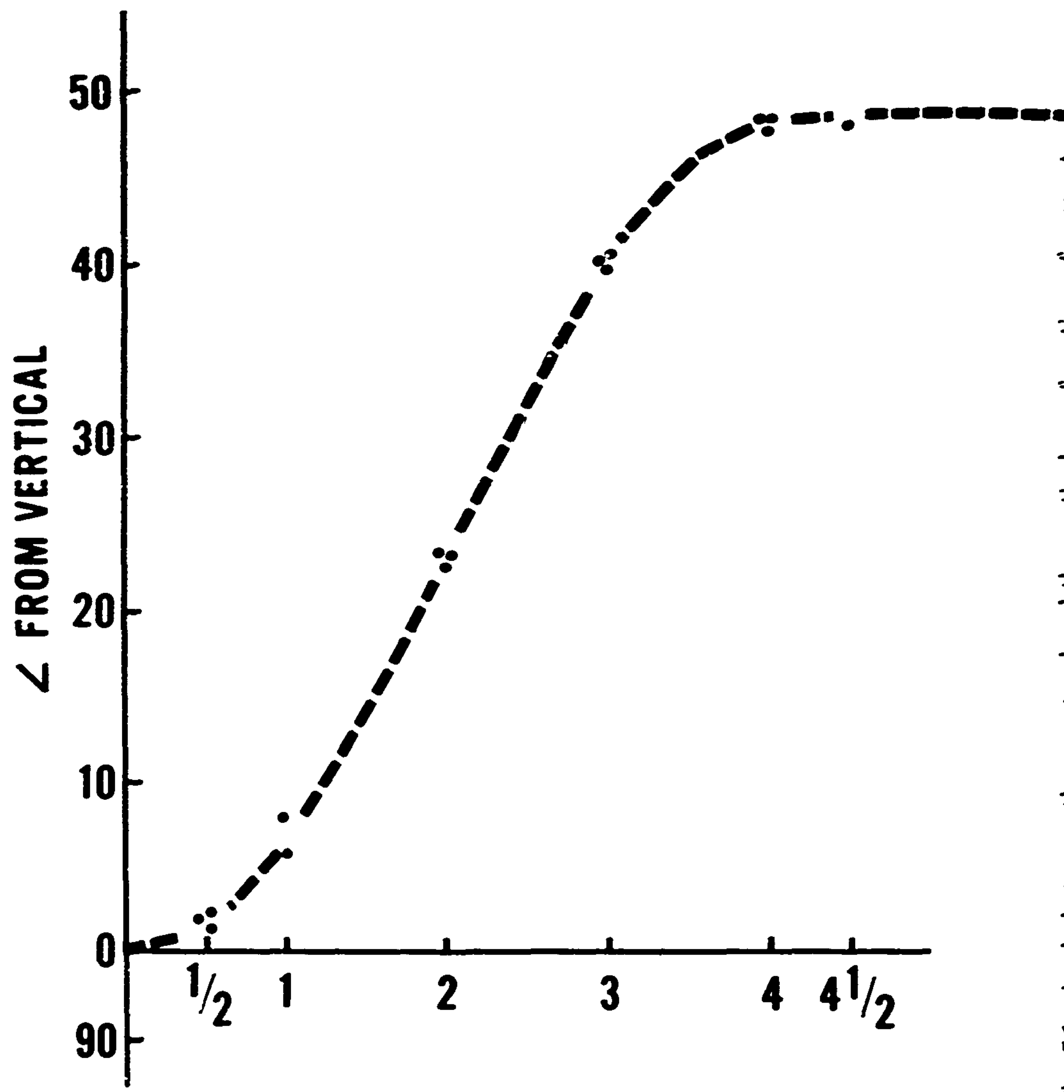


Fig. 56. Angle between the gunstand and the vertical as a function of current.

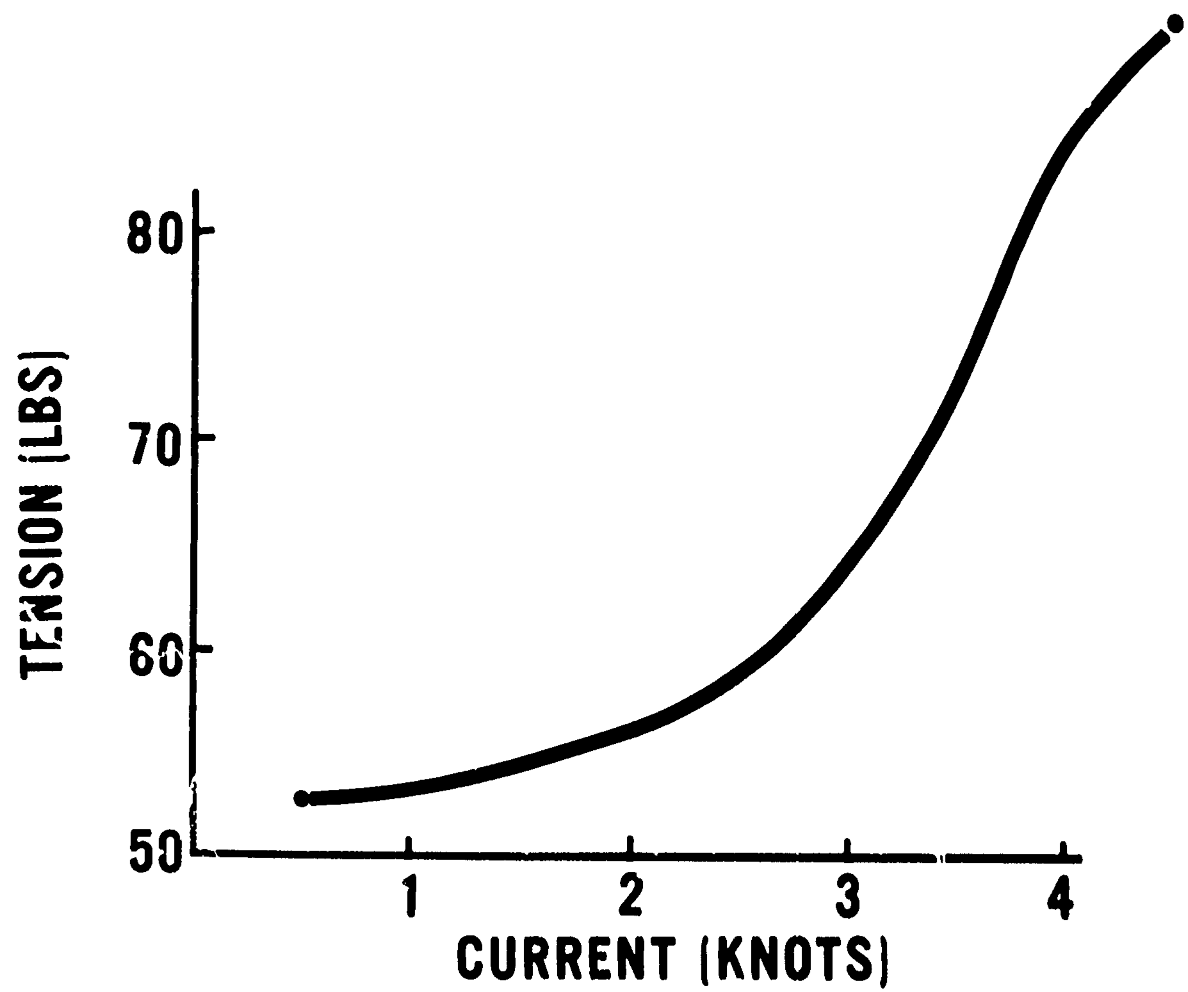


Fig. 57. Explosive embedment penetrometer cable tension.

ANGLE	PHOTOGRAPHIC		TRANSDUCER
	GUN	CABLE	CABLE
½	2	2	2
2	27	24	23
4	47	41	48

Fig. 58. Comparison of photographic and force transducer.

Even though the vertical penetration is reduced, it still gives an indication of the sediment's ability to resist the movement of the projectile.

(2) **Soft Sediment (Line B).** In this case, the projectile enters the sediment at an angle ϕ, and under the force of the extraction test, the cable moves through the sediment from position A to position B. The sediment is soft and the anchor remains in place while the cable is moved toward the vertical.

The vertical penetration indicated in this case will be less than the actual penetration by a factor directly proportional to the cosine of the angle of incidence.

Since the sediment is soft, Method II could also be used to obtain a more accurate estimation of the vertical penetration.

In both cases, the extraction force will also supplement the information obtained from the penetration values.

(3) **Common Case (Line C).** In the cases most commonly occurring in actual sediments, the cable will follow a path similar to Line C when the penetration is measured. It will then be between Case A or B.

Letting

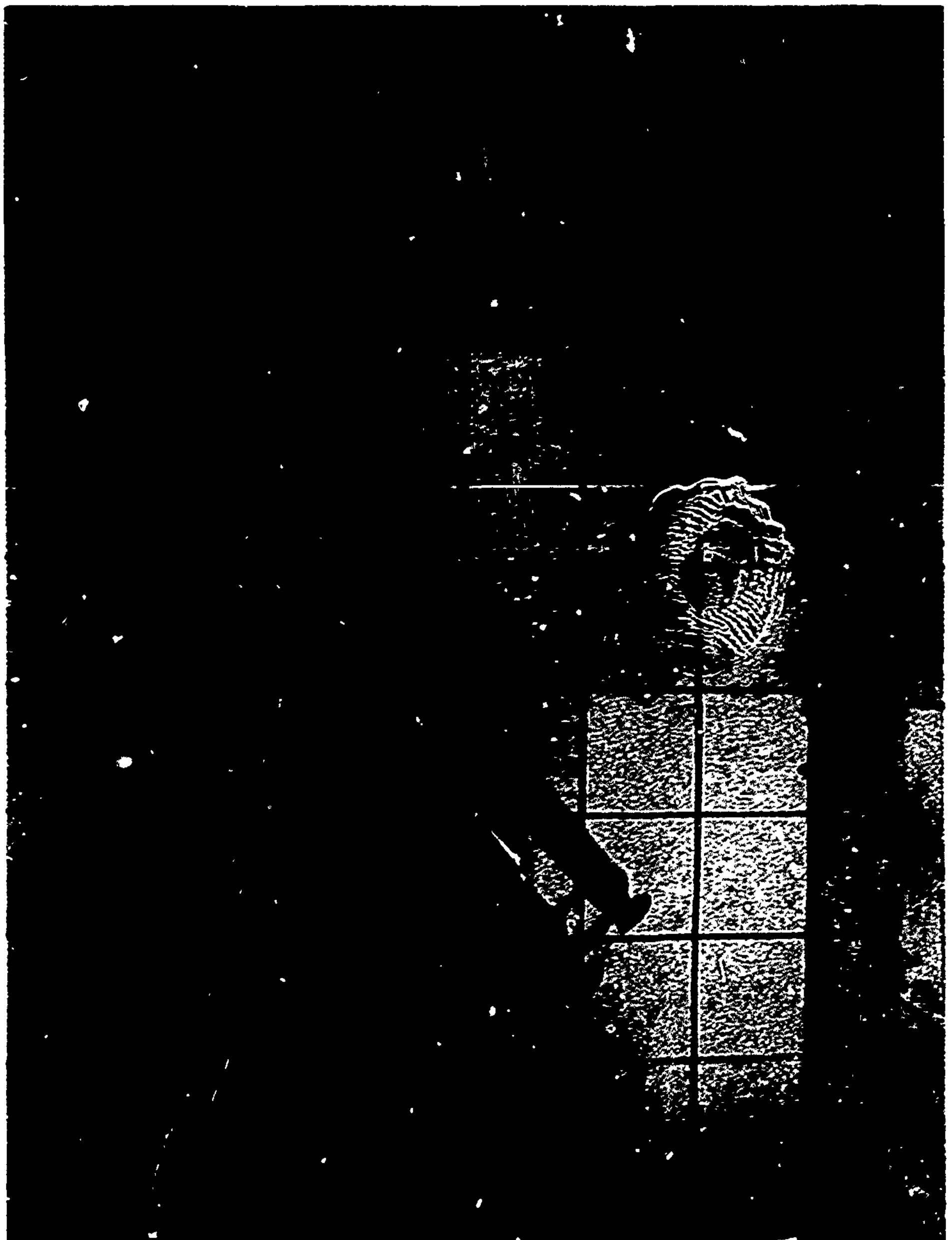
P_v = vertical depth of the projectile

P = penetration of EEP projectile into ocean floor

and applying Method I (paragraph III B).

V3040

Fig. 59. Photograph of gunstand in a 2-knot current.



V3051

Fig. 60. Photograph of gunstand in a 4-knot current.

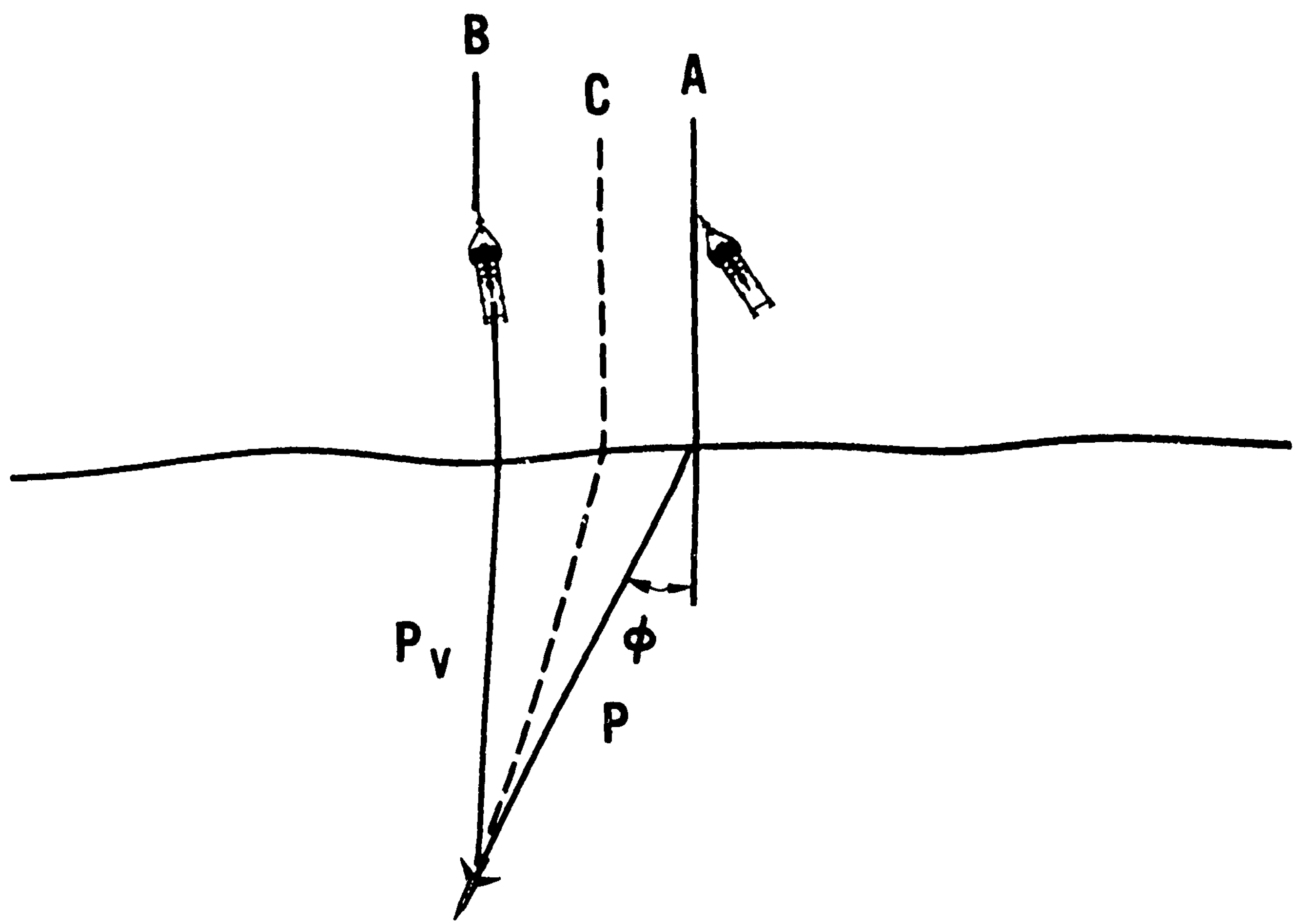


Fig. 61. Error analysis.

$$P_v = C\text{-}H_1\text{-}R_1\text{-}(P\text{-}P_v)$$

$$= C\text{-}H_1\text{-}R_1\text{-}[C\text{-}H_1\text{-}(\cos\phi\,(C\text{-}H_1\text{-}R_1))]$$

$$= (C\text{-}H_1\text{-}R_1)\cos\phi$$

or

$$P_v = P\cos\phi$$

Therefore, the maximum error between the recorded penetration and the vertical penetration is proportional to the cosine of the angle of incidence of the gunstand and is independent of the serve cable length and other factors.

Figure 62 shows the current speed versus maximum possible error. It is emphasized that these are maximum values for a hypothetical soft sediment. The error in a real sediment will be less than these values.

The requirements to which the EEP was designed state a limit of 2 knots of current. Figure 62 shows that the maximum penetration error is 10 percent. This is not significant in view of the fact that extraction force values will also help to give a more accurate indication of the sediment's strength.

CURRENT (KNOTS)	ANGLE OF INCIDENCE (DEGREES)	MAXIMUM ERROR (PERCENT)
1	7	1
2	24	10
3	40	24
4	48	32

NOTE: THESE VALUES WERE DERIVED FOR A HYPOTHETICAL CASE. THE ERROR IN A REAL SEDIMENT WILL BE LESS THAN, BUT MAY APPROACH, THESE VALUES.

Fig. 62. Maximum error of penetration data vs current velocity.

2. **Excursion Determination.** The excursion of the gunstand from under the MSB and the amount of wire rope required to reach the ocean bottom can be determined theoretically.

The forces acting on a segment of the wire rope are its weight, the lift and drag forces exerted by the current, and the force of the gunstand at the lower end.

The force per unit length is

$$d = C_L \frac{\rho V^2}{2g} A + C_D \frac{\rho V^2}{2g} A$$

The lift and drag coefficients, C_L and C_D are given by Hoerner[5]

$$C_L = 1.1 \sin^2 \alpha \cos \alpha .$$

$$C_D = 1.1 \sin^3 \alpha .$$

Writing an equation for a unit element of the wire rope (Fig. 63)

$$T' \sin = w + F_2 + d_v .$$

$$T' \cos = d_H + F_1$$

$$\frac{dy}{dx} = \tan \alpha = \frac{w + F_2 + d_v}{d_H + F_1}$$

where w = weight of the cable per unit length

d_v = vertical component of drag (lift)

d_H = horizontal component of drag

F_G = force exerted on the cable by the gunstand

$F_1 = F_G \sin \alpha_i .$

$F_2 = F_G \cos \alpha_i .$

α_i = angle between the wire rope and the horizontal at the gunstand

This equation was programmed for a digital computer to integrate the equation from the gunstand up the cable. The force of the gunstand (F_G) and the initial

[5]Sighard F. Hoerner, "Fluid-Dynamic Drag." Published by the author, 1965.

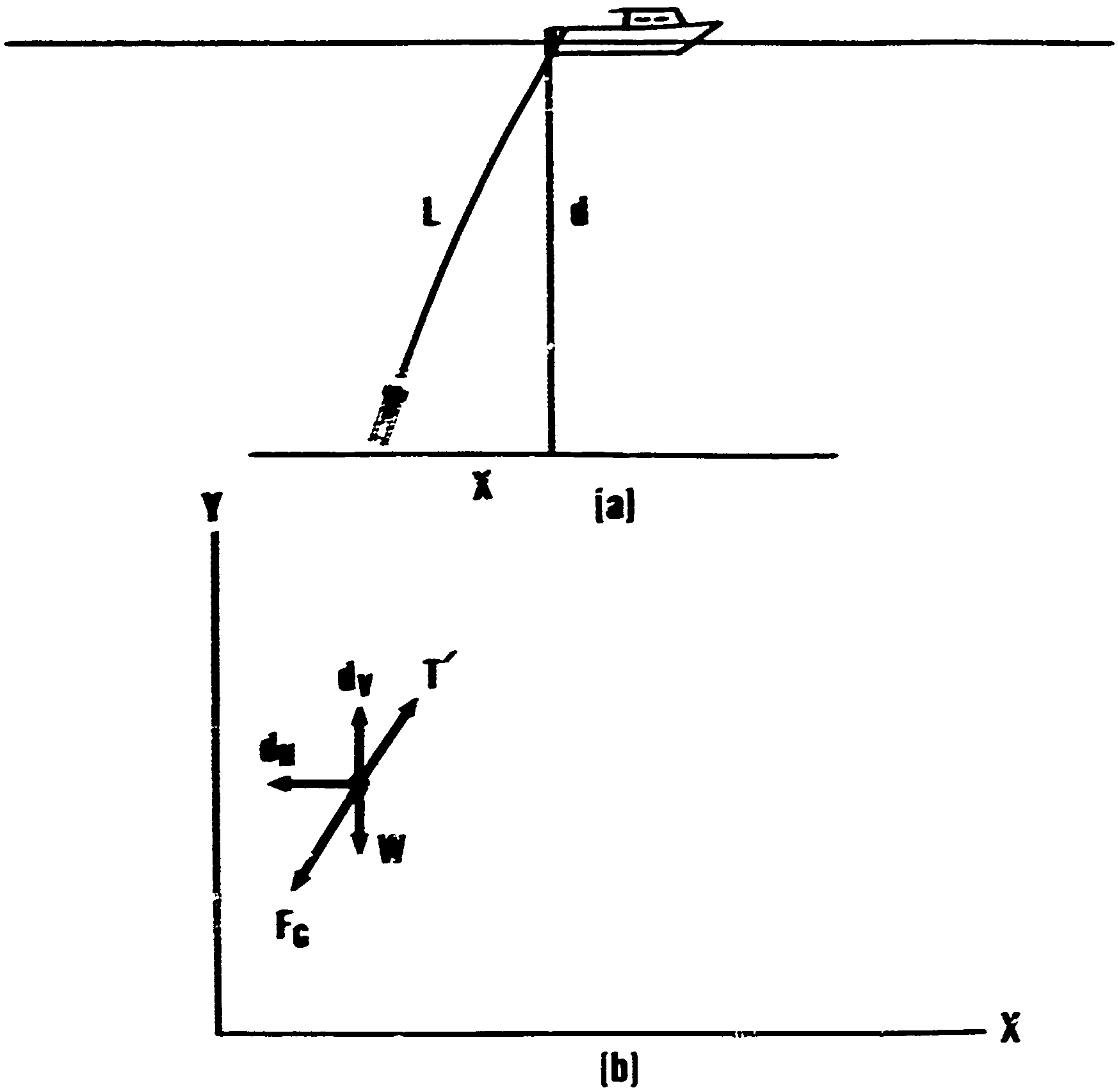


Fig. 63. Forces on unit element of EEA wire rope.

angle (α_i) were determined experimentally during the tow tank test.

The excursion of the gunstand at various currents is shown in Fig. 64. The graph is entered on the right side with the water depth (d) and read across to the appropriate current. Dropping vertically from that point on the current speed curve yields the distance (x) of the gunstand from a point directly below the stern of the MSB.

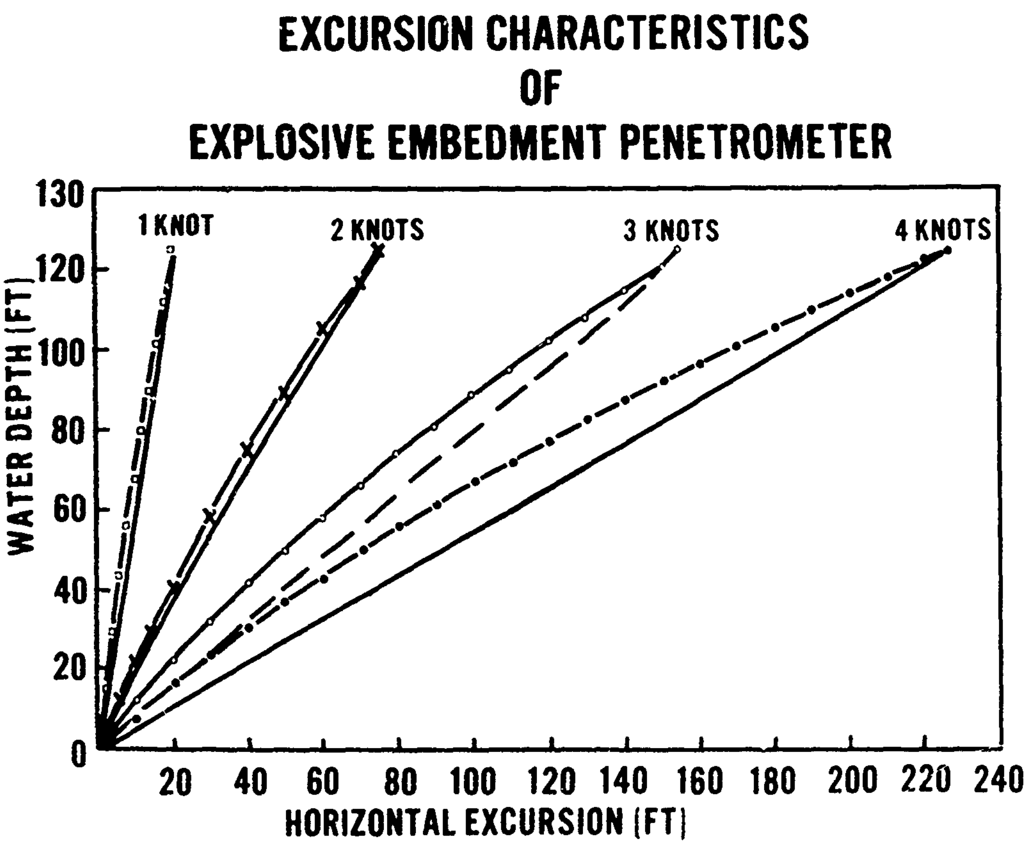


Fig. 64. Gunstand excursion as a function of current velocity and water depth.

Figure 65 shows how much wire rope must be paid out to allow the gunstand to reach the bottom in various currents.

In a 2-knot current and 120 feet of water (the limiting conditions), 138 feet of cable must be paid out to reach the bottom.

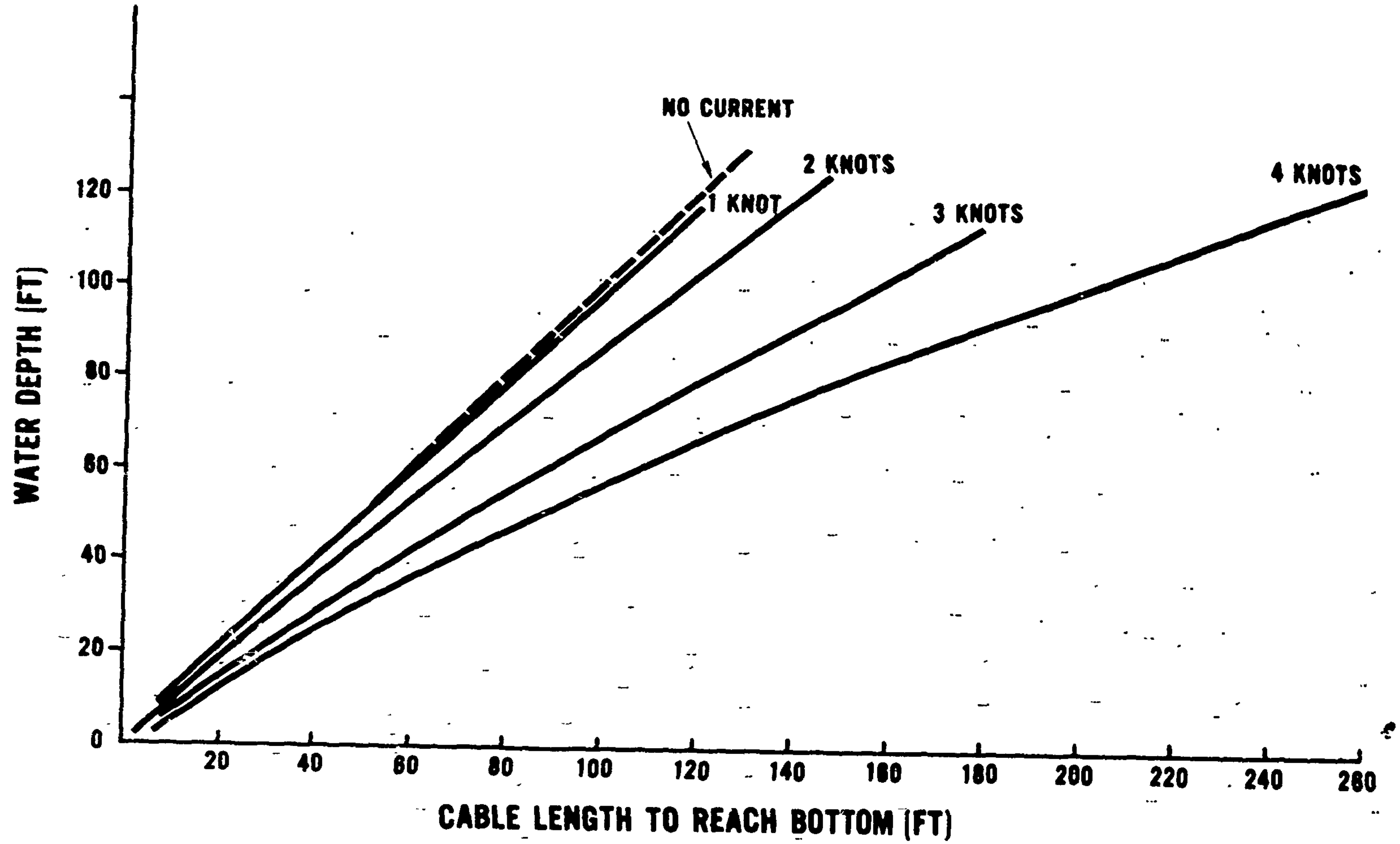


Fig. 65. Cable length to reach the bottom.

IV. CONCLUSIONS

It is concluded that:

1. Mooring Site Survey Equipment can determine the suitability of an offshore area for the deployment of the Multi-Leg Tanker System. The AUSE and EEP complement each other to achieve the mission with a degree of accuracy and reliability that is not equaled by the deployment of one of the components alone.

2. The combination of a sub-bottom profiler and side scan sonar is far more valuable than either alone. The side scan sonar aids in the identification of the surface sediments on the sub-bottom profiler.

3. The side scan sonar can identify manmade objects, natural terrain features and ocean bottom surface sediment characteristics.

4. The sub-bottom profiler can detect discrete sediment layers approximately 1 foot in thickness.

5. The sub-bottom profiler can determine the general sediment type of the ocean floor and can distinguish between sand, rock, mud, and clay.

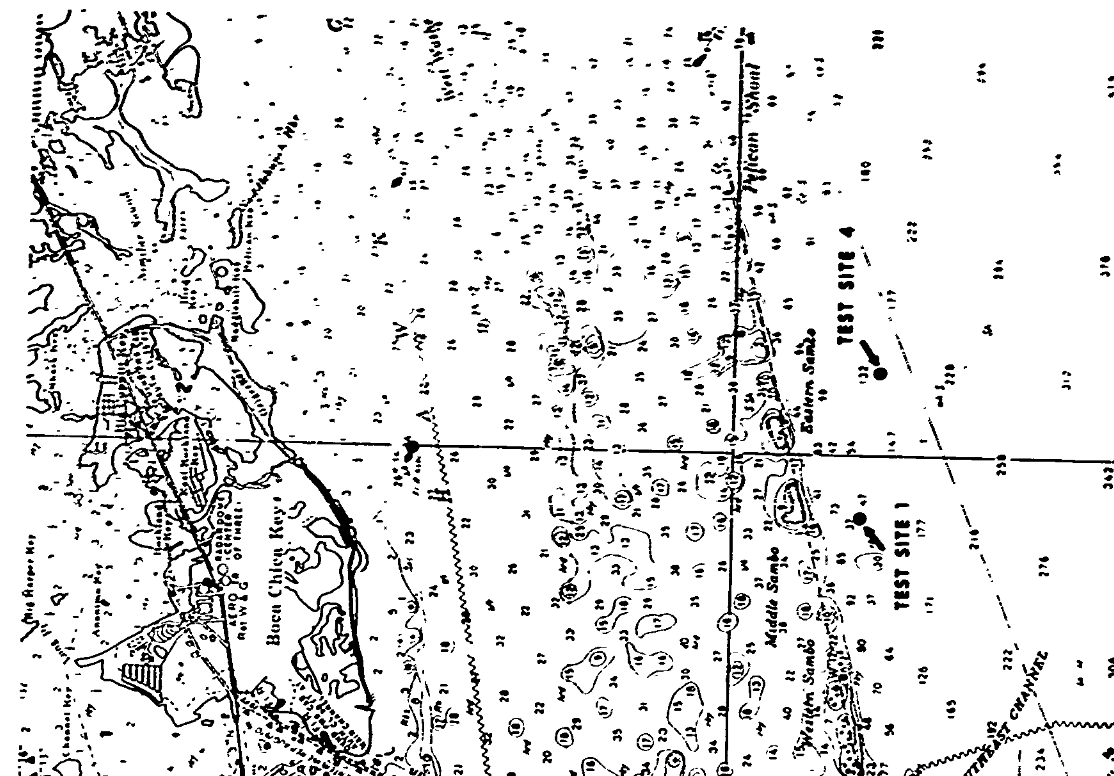
6. Limited testing has shown that enlisted personnel of MOS 51G with proper training and sufficient experience can operate the AUSE.

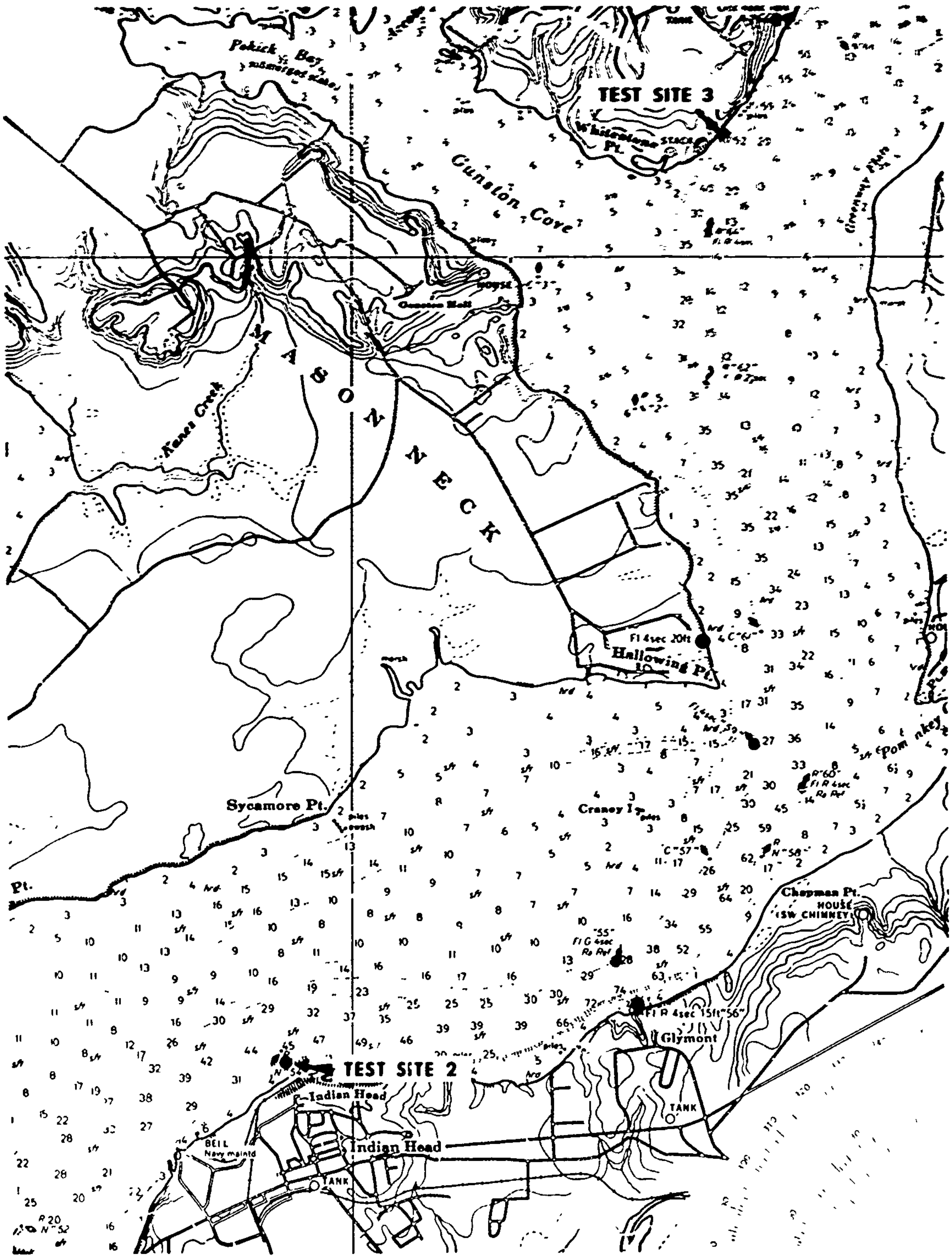
7. A correlation exists between the penetration and extraction forces of the EEP and the penetration and holding power of the USAMERDC XM-200/XM-50 EEA.

8. The Mooring Site Survey Equipment can be deployed from a 25-foot Coast Guard Motor Surfboat in light seas.

APPENDIX A

TEST SITES


KEY WEST
Boca Chica Keys
TEST SITE 4
TEST SITE 1
Eastern Sambo
Middle Sambo
Western Sambo
Pelican Shoal
SOUTHEAST CHANNEL
Western Head
RED SECTOR


TEST SITE 3
Pohick Bay
Gunston Cove
Whitestone Pt.
Gunston Hall
MASON NECK
Kanes Creek
Fl 4sec 20ft
Hallowing Pt.
Sycamore Pt.
Craney I.
Chapman Pt.
HOUSE (SW CHIMNEY)
Fl R 4sec 15ft "56"
Glymont
TEST SITE 2
Indian Head
BELL
TANK

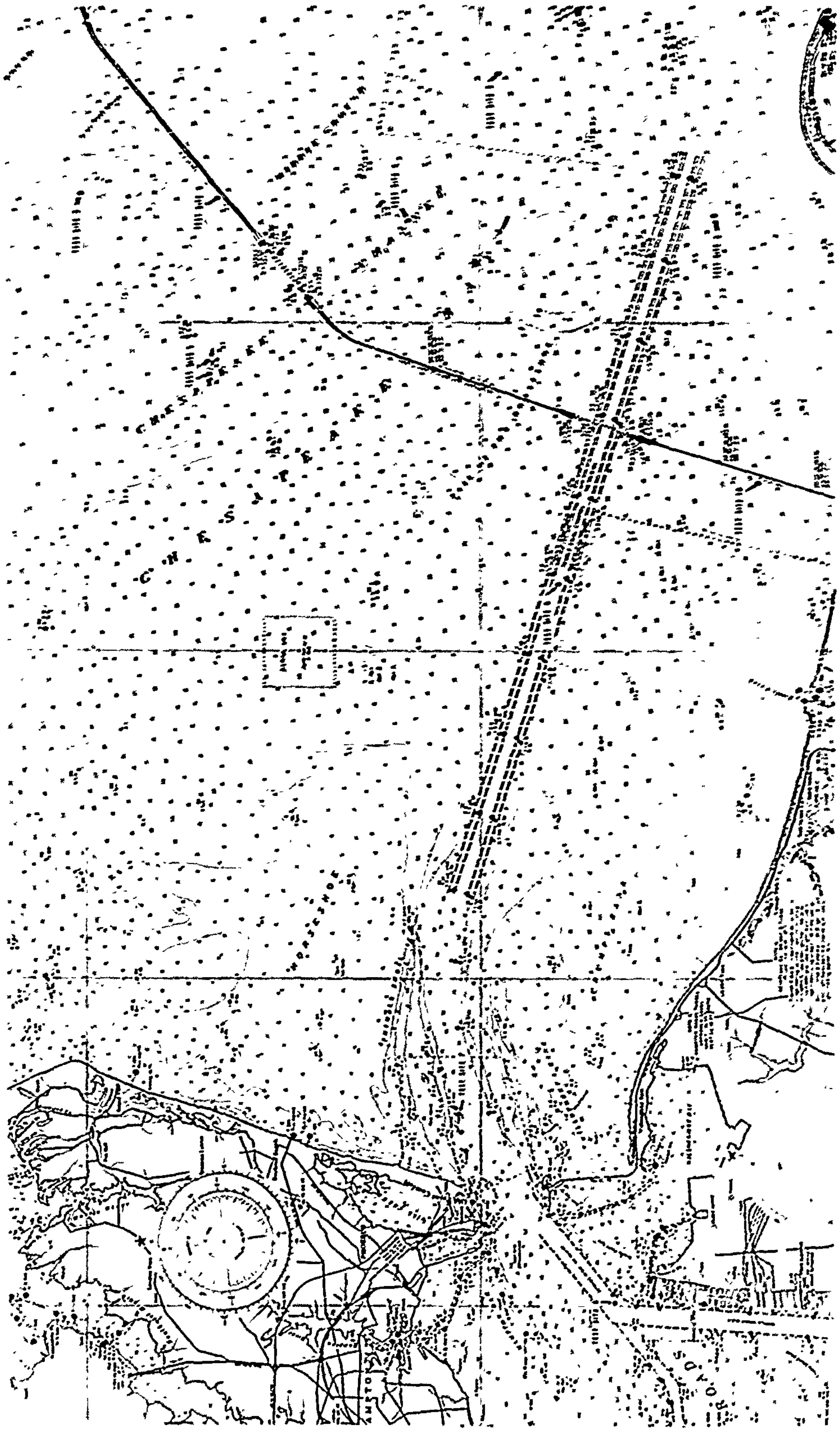
Chesapeake Bay Test Site Locations

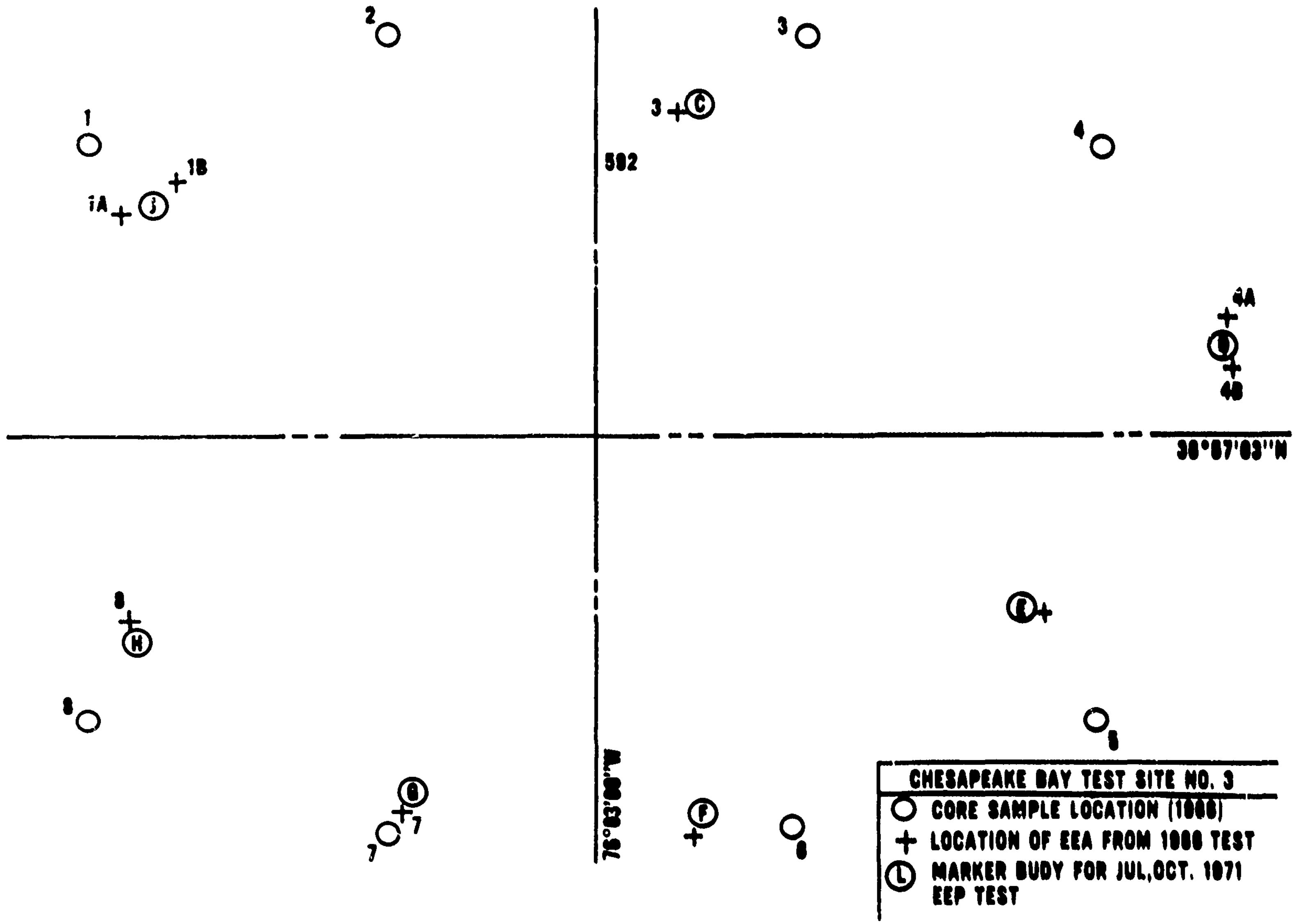
Test Site	Location	Marker Buoy	Type of Bottom	Water Depth	Source of Information
1	37° 03.6'N, 76° 05.8'W	–	10' SM over CL, Firm– Compact	40	Footnote 2, p. 260 (DH– 1)
2	37° 04.9'N, 76° 03.4'W	B	SM, 12– 22 bpf,[1] firm	40	Footnote 2, p. 260 (DH– 3)
3	37° 57.15'N, 76° 02.93'W	C	CH,OH	42	Footnote 3, p. I– 7 (bore #3)
	36° 57.11'N, 76° 02.81'W	D	SP,SC	43	Footnote 3, p. I– 8 (bore #4)
	36° 57.01'N, 76° 02.85'W	E	SP,SM	45	Footnote 3, p. I– 9 (bore #5)
	36° 56.95'N, 76° 02.95'W	F	SP,ML	47	Footnote 3, p. I– 10 (bore #6)
	36° 56.96'N, 76° 03.06'W	G	SP,SM	46	Footnote 3, p. I– 11 (bore #7)
	36° 57.01'N, 76° 03.11'W	H	SM	45	Footnote 3, p. I– 12 (bore #8)
	36° 57.13'N, 76° 03.10'W	J	SP,SM	45	Footnote 3, p. I– 5 (bore #1)
4	37° 00.8'N, 76° 03.4'W		SM, 25– 35 bpf	50	Norfolk District, Corps of Engineers
5	36° 59.83'N, 76° 01.1'W		OL– SM, med. to soft	50	Norfolk District, Corps of Engineers
6	36° 59.38'N, 76° 10.08'W		SM,OH,SM	43	Norfolk District, Corps of Engineers
7	37° 00.28'N, 76° 17.16'W		unk.	105	
8	37° 58.30'N, 76° 19.16'W		OH med. to soft	50	Norfolk District, Corps of Engineers
9	37° 03.33'N, 76° 03.1'W (C– 50)		SM, 25 bpf, firm	25	Chesapeake Bay Bridge– Tunnel Commission
10	36° 56.33'N, 76° 07.37'W (A– 115)		silt	24	Chesapeake Bay Bridge– Tunnel Commission

[1] bpf – blows per foot, 140-lb hammer, 30-in. drop with 1-3/8- by 3-1/2-in. standard penetration spoon.

[2] John A. Christians and Edward P. Meisburger, "Development of Multi-Leg Mooring System, Phase A – Explosive Embedment Anchor." USAMERDC Report 1909-A, December 1967.

[3] U. S. Army Test and Evaluation Command, "Integrated Engineering and Service Tests of System, Vessel Mooring, Multi-Leg," USATECOM Project No. 7-4-0359-0./02.




CHESAPEAKE BAY TEST SITE NO. 3
MARKER BUOY FOR JUL,OCT. 1971 EEP TEST
76°03'00"W
582

Chesapeake Bay Test Sites
Core Sample Log

Site 1 PR	Site 1 Classification		Depth	Site 2 PR	Site 2 Classification	
	SM	dark grey silty sand, terrace shells			SM	fine grey silty sand
	SP-SM	silty fine sand	5			
65	SM			12		
	SP-SM	silty fine sand	10			
	CL	sandy silty clay				
11			15			
			20	22		
			25			

Chesapeake Bay Test Sites
Core Sample Log

Site 3(C) PR	Site 3(C) Classification		Depth	Site 3(D) PR	Site 3(D) Classification	
0	CH-OH	clay and silt, little organic matter dark grey (occas. traces of sand)		4	SM	fine sand, little silt, dark grey-brown
			5	26		fine to coarse sand trace of silt, brown
			10	26	SP	
					SP	fine to med. sand, brown
			15	18	SC	sand & shell, gray
2			20	9, 12	ML	silt & clay, some very fine sand & shell frag., dark grey
3				45	SM	very fine sand & silt, dark grey
2	OH-PT	lenses of peat & silt	25	31, 17		

Chesapeake Bay Test Sites
Core Sample Log

Site 3(E)				Site 3(F)		
PR	Classification		Depth	PR	Classification	
6	SP	fine sand & trace of silt brown and dark grey		5	SP-SM	fine sand & traces of silt, brown & dark grey
			5	9		
Soft	SM	fine sand, some silt, dark grey				
				8	ML	silt, some clay, little sand, dark grey
23	SM	fine sand & a little silt, dark grey	10	16	SM	fine to med. sand, little silt
			15	11	ML	silt, some clay, little sand, dark grey
Soft				Soft		
3 2	MH or OH	silt, some clay, occas. lens of sand, dark grey trace of organic mat.	20			
				11	SM	fine to med. sand, little silt, dark grey
3	CH		25	3	MH-OH	silt & clay, trace of organic matter, dark grey

Chesapeake Bay Test Sites
Core Sample Log

Site 3(G) PR	Site 3(G) Classification		Depth	Site 3(H) PR	Site 3(H) Classification	
4	SP SM	fine sand, traces of little silt, dark grey & brown		4	SM	fine sand, little silt, tr. organic matter, dark grey
			5	16	SP	fine to course sand trace of silt, grey
				1	SP-SM	fine and med. sand in layers with trace of little silt, dark grey
6	MH	silt & clay, trace of sand, dark grey, slightly organic		7		
			10			
18	SC	sand & shell frag. and clay & silt		50		
38	SM	very fine sand & silt, dark grey				
			15	70		
80	SM	very fine sand & silt, dark gray				
				3		
			20	3	CH	clay & silt with lenses of peat. dark blue-grey
			25	1		

Chesapeake Bay Test Sites
Core Sample Log

PR (Site N(J))	Classification (Site N(J))		Depth	PR (Site 4)	Classification (Site 4)	
8	SP	sand, dark grey			SM	silty, fine sand dark grey
			5			
				30		
				25		
			10			
14	SC	sand & shell				
			15	28		
10					SP-SM	silty med. to fine sand, brown
42	SM	very fine sand & silt. dark grey with occas lens of (ML) silt sand	20		CL	sandy silty clay, trace shells, dark grey
22				35		
				62		
17			25	15		
				16		
20						

Chesapeake Bay Test Sites
Core Sample Log

Site 5 PR	Site 5 Classification		Depth	Site 6 PR	Site 6 Classification	
	SM	fine sand, clay & silt			SM	fine sand, little silt
	OL-SM	organic silt and very fine sand, micaceous, trace shell grags.	5		SP-SM	fine to med. sand shell frags. little silt, grey non plastic
			10		OH	organic clay & silt trace of very fine sand, dark grey high plast.
			15		SM-OL	fine to very fine sand & organic silt, trace of shell frags. med. plast.
					SM	
			20			
			25			

Chesapeake Bay Test Sites
Core Sample Log

Site 8 PR	Site 8 Classification	Depth	Site 9 PR	Site 9 Classification
OH	organic clay & silt, dark grey plasticity high		22	fine sand, some silt, trace of shells, grey
		5		
		10	40	
		15	6	fine sand, some silt pockets, grey
		20	6	
		25		

Chesapeake Bay Test Sites
Core Sample Log

Site 10

PR	Classification		Depth	PR	Classification	
WR		soft grey clayey silt, trace fine sand				
			5			
			10			
			15			
			20			
			25			

APPENDIX B

JULY 1971 TEST DATA
CHESAPEAKE BAY TEST SITES

EXPLOSIVE EMBEDMENT PENETROMETER TEST DATA
CHESAPEAKE BAY TEST SITES
JULY 1971

Test Site	Bottom	Water Depth (ft)	Penetration (ft)	Avg. Load (lb)	Max. Load (lb)
3	clay, silt	53	23	200–500	600
3	sand, trace silt	53	20	250–375	1400
3	sand, trace silt	53	10	––	pin sheared
3	mostly sand, over clay	53	9	900–1050	pin sheared
4	silty, fine sand	40	18	cable broke	
4	silty, fine sand	40	14	––	pin sheared
4	silty	40	14	cable broke	
2	fine gray silty sand	40	6	––	pin sheared
2	fine gray silty sand	40	6	––	pin sheared
6	dense sand over OH	45	11	600–1000 (clay)	sheared (sand)
6	dense sand over OH	45	11	850–1125	pin sheared
6	dense sand over OH	45	12	cable broke	
6	dense sand over OH	45	12	850–1000	pin sheared
10	silt	24	27	no pull-out test	
10	silt	24	25	no pull-out test	

one (1)-inch fluke

Wave Data
Chesapeake Bay Bridge-Tunnel
19-28 July 1971

Time	0000		0400		0800		1200		1600		2000	
1971	Period (sec)	Ht. (ft)	Period (sec)	Ht. (ft)	Period (sec)	Ht. (ft)	Period (sec)	Ht. (ft)	Period (sec)	Ht. (ft)	Period (sec)	Ht. (ft)
19 Jul		0.0	no record		no record		no record		3.0	1.0	3.0	1.0
20 Jul		0.0	2.5	0.7	2.5	0.7		0.0	2.0	0.7	3.0	0.7
21 Jul		0.0	3.5	2.5	4.0	3.0	3.0	1.0	3.0	1.0	4.0	1.0
22 Jul	2.5	0.7	2.0	0.7	2.0	0.7	2.5	1.0	3.0	1.0	3.0	1.0
23 Jul		0.0		0.0	4.0	1.5	3.5	1.0	3.0	0.7	4.0	1.5
26 Jul	2.0	0.7	2.0	0.7	2.0	0.7		0.0	2.0	1.2	2.0	0.7
27 Jul	3.0	1.2	2.0	1.0	2.5	1.5	2.5	1.0		0.0		0.0
28 Jul	2.5	0.7	2.0	0.7	2.5	1.5	3.0	1.0	2.0	0.7		0.0

Obtained from U. S. Army Coastal Engineering Research Center, Washington, D. C.

APPENDIX C

OCTOBER 1971 TEST DATA
CHESAPEAKE BAY TEST SITES

EXPLOSIVE EMBEDMENT PENETROMETER TEST DATA
TEST SITE 3
15 OCT 71
COMPARISON OF EEP AND XM-200 EEA

	Penetrometer			XM-200 EEA		
Buoy Letter	Penetration (ft)	Predominant Load (lb)	Failure Penetration (lb)	Penetration (ft)	Force	Rating (%)
C	14-16	400-800	12-14	38	100,000	Good (50)
D	15-17	800-1000	9-14	16-28	105,000	Good (50)
E	12-14		9-10	28	120,000	Good (60)
F	17	400-800 C 10-4 ft		36	70,000	Fair (35)
G	14-15		11	24	110,000	Good (51)
H	16		12-14	34	195,000	Very good (97)
J	18		12-15	34-37	45,000	Poor (24)

Explosive Embedment Penetrometer Test
Chesapeake Bay Test Sites
15 Oct 1971

Test No.	Buoy No.	Penetration (ft)	Load Range (lb)	Shear Point (lb)
1	J	18	--	1900 @ 15 ft
2	J	19	--	1800 @ 12 ft
3	C	--	400-600	1500 @ --
4	C	16	--	1600 @ 14 ft
5	C	14	800-1000	1600 @ 12 ft
6	D	8	--	1700 @ 3 ft
7	D	17	800-1000	1500 @ 14 ft
8	D	15	--	1600 @ 9 ft
9	E	12	--	1600 @ 10 ft
10	E	10	--	1700 @ 9 ft
11	E	14	--	1600 @ 9 ft
12	F	--	--	1700 @ --
13	F	17	400-600 @ 12-4 ft	1500 @ 2 ft (?)
14	F	16	400 @ 16-8 ft	1600 @ 1 ft (?)
15	F	17	400-800 @ 10-4 ft	1500 @ 1 ft (?)
16	G	15	--	1600 @ 11 ft
17	G	14	--	1500 @ 11 ft
18	H	16	--	1600 @ 14 ft
19	H	15	--	1500 @ 12 ft

Wave Data
Chesapeake Bay Bridge-Tunnel
12-15 Oct 1971

Date	Hour	Significant Period	Significant Height
12 Oct 71	1300		0.0
	1900		0.0
13 Oct 71	0100		0.0
	0700		0.0
	1300	3.0	0.7
	1900		0.0
14 Oct 71	0100	3.0	1.0
	0700	3.0	0.7
	1300	4.0	0.7
	1900	3.0	1.0
15 Oct 71	0100		0.0
	0700	0.4	0.7
	1300		0.0
	1900	3.0	1.0

Obtained from U. S. Army Coastal Engineering Research Center, Washington, D. C.

APPENDIX D

POTOMAC RIVER TEST DATA

Explosive Embedment Penetrometer Test
Potomac River Test Sites
1 Nov 1971

Location	Penetration (ft)	Max. Load (lb)	Predominant Load (lb)	Comments
Potomac R. site 2	24	1700 (sheared)	600-800 (up to 20 ft)	Silty clay on surface.
Potomac R. site 2	18	1900 (sheared)	--	Pin sheared at 11 ft penetration.
Potomac R. site 3	--	--	--	Broke cable on firing.
Potomac R. site 3	29	400	--	Soft grey silty clay.
Potomac R. site 3	29	400	300-400	--
Potomac R. site 3	26	400	300-400	--

APPENDIX E

KEY WEST, FLORIDA TEST DATA

EXPLOSIVE EMBEDMENT PENETROMETER TEST
TEST SITES 1 & 4
KEY WEST, FLORIDA

10 Feb 72

Test	1	2	3	4	5	6	7	8
Test Site	Site 1	Site 1	Site 1	Site 1	Site-4	Site 4	Site 4	Site 4
Date	10 Feb 72	10 Feb 72	10 Feb 72	10 Feb 72	10 Feb 72			10 Feb 72
Water Depth	45 ft	45 ft	45 ft	45 ft	140 ft		150 ft	150 ft
Wind	10 kts.	10 kts.	10-15 kts.	10-15 kts.	10-15 kts.		15 kts.	
Waves	2-3 ft	2-3 ft	2-3 ft	2-3 ft	3-4 ft		4-5 ft	
Bottom Mat'l	←	Coral	→		Soft			
Penetration	4	0	5	4	14	28	26	
Load	Shear		Shear	1200		1400	Shear	
Mat'l on Flukes	Coral Chunks	–	–	–				
Comments	Shank bent at top of flukes.	Shank bent at top of flukes; apparently no penetration.			138 ft of cable out.		Boat dragging anchor.	

APPENDIX F

OPERATOR TRAINING COURSE OUTLINE

NEW EQUIPMENT TRAINING PLAN FOR ELECTRONIC UNDERWATER SURVEY EQUIPMENT CONTRACT DAAK02-71-C-0410

PART I. CLASSROOM TRAINING – 40 hours

A. Basic Sonar Concepts – (4 hours)

1. Principles of Sonar in general – (2 hours)

    a. Sound Sources
    b. Hydrophones
    c. Beam Patterns of Arrays versus Frequency
    d. Attenuation in Water and Sediment versus Frequency
    e. Source Level
    f. Target Strength
    g. Noise
    h. Sonar Equation
    i. Amplifiers
    j. Time Varied Gain
    k. Display of Data (Recorders)

2. Seismic Profiling Sonar – (1 hour)

    a. Frequencies Used
    b. Sound Sources
    c. Hydrophones
    d. Beam Patterns
    e. Recorders

3. Side Scan Sonar – (1 hour)

    a. Concept
    b. Frequencies versus Range/Resolution/Beam Pattern
    c. Dual Channel Recorder

B. Introduction to the Electronic Underwater Survey (EUS) Equipment – 12 hours

1. Recorder – (8 hours)

    a. Driver Circuit 5 kHz
    b. Driver Circuit 100 kHz
    c. Sonar Amplifier
    d. 5 kHz Amplifier
    e. Trigger and Gate Module
    f. Negative Ramp Generator Module
    g. Print Amplifier
    h. Switching Circuit
    i. Test Circuit
    j. Power Supplies and Inverter
    k. Miscellaneous

2. Side Scan Towed Body – (2 hours)

3. Seismic Profiler – (2 hours)

    a. Towed Sound Source
    b. Hydrophone

C. Operation of EUS Equipment – 10 hours

1. Side Scan Sonar System – (4 hours)

    a. Deployment of Towed Body
    b. Tow Depth versus Speed and Cable Length
    c. Range Controls
    d. Gain Control
    e. Time Varied Gain Settings
    f. Output Test Procedure
    g. Receiver Test Procedure
    h. Scale Lines

2. Seismic System – (4 hours)

    a. Deployment of Towed Sound Source
    b. Deployment of Hydrophone
    c. Operating Speed

d. Range Control
e. Module Control
f. Power Level
g. Gain Control
h. TVG Control
i. Output Test Procedure
j. Receive Test Procedure

3. Recorder Operation in General – (2 hours)

a. Paper Change
b. Helix Blade Adjustment
c. Panel Light Intensity
d. Fuses
e. Event Mark
f. Elapsed Time Meter

D. <u>Maintenance of EUS Equipment</u> – (6 hours)

1. Routine Maintenance of Recorder – (2 hours)

a. Fuse Replacement
b. Lamp Replacement
c. Helix Replacement
d. Endless Loop Electrode Replacement

2. Troubleshooting – (4 hours)

a. Effect of Failure of Cards:

(1) Trigger and Scale Line
(2) Negative Ramp Generator
(3) Print Amps
(4) Transducer Driver
(5) Relay Boards
(6) Sonar Amps
(7) Test Boards

b. Effect of Fuse Failure

E. <u>Record Interpretation General</u> – (6 hours)

1. Side Scan Records – (3 hours)

   a. Density of Bottom Return
   b. Size of Targets
   c. Shadows

2. Seismic Records – (3 hours)

   a. Outcroppings
   b. Stratification
   c. True Depth Determination

F. <u>Specific Application to Selecting Mooring Sites</u> – (2 hours)

   1. Absence of Rocks and Outcroppings
   2. Firm Sediment
   3. Depth of Sediment

PART II. SHIPBOARD TRAINING – 40 hours

A. <u>Installation of Equipment</u> – (4 hours)

1. Recorder – (1 hour)

   a. Mounting
   b. Power Connections

2. Side Scan Towed Body – (1 hour)

   a. Tie point of cable for various depths and speeds
   b. Length of cable used for various depths and speeds
   c. Connection to Recorder

3. Seismic Sound Source – (1 hour)

   a. Tie Point of Cable
   b. Length of Cable
   c. Connection to Recorder

4. Hydrophone – (1 hour)

   a. Use of Boom

b. Adjustment of Depth and Relative Position to Sound Source
c. Connection to Recorder

B. <u>Operation of Equipment</u> – (12 hours)

1. Side Scan Sonar – (5 hours)

a. Range Settings
b. Gain Settings
c. Test Procedures
d. Actual Operation by Each Student

2. Seismic System – (5 hours)

a. Range Setting
b. Module Control
c. Gain Setting
d. Power Control
e. Test Procedure
f. Actual Operation by Each Student

3. General Operation – (2 hours)

a. Blade Adjustment
b. Light Intensity
c. Event Mark
d. Paper Change
e. Actual Operation by Each Student

C. <u>Maintenance of Equipment</u> – (6 hours)

1. Routine Maintenance by Each Student – (2 hours)

a. Fuse Replacement
b. Lamp Replacement
c. Helix Replacement
d. Endless Loop Electrode Replacement

2. Troubleshooting – (3 hours)

a. Instructor Induces Various Failures. Students endeavor to Ascertain which P/C Card or Fuse has Failed.

D. Safety Measures – (2 hours)

1. Maneuvering with Towed Bodies – (1 hour)

a. Large Turning Radius
b. Stopping

(1) Haul in all Tow Lines to Minimum Scope Prior to Stopping.
(2) Make Sure no Lines are Under Boat.
(3) Make Sure S. S. Towed Body will not Strike Bottom.

c. Getting Underway

2. Recorder – (1 hour)

a. Turn Off Power before Opening any Covers
b. Short Out Energy Storage Capacitors before Servicing

E. Operation in Various Areas – (16 hours)

Repeat B in other areas to attain more experience in operation and to observe varying bottom conditions.

PART III. LIST OF AREAS FOR TRAINING

A. Areas Having Variety of Subbottom Features

1. Salem Harbor
2. Offshore between Marblehead and Boston Outer Harbor
3. Boston Outer Harbor
4. Boston Inner Harbor

PART IV. QUALIFICATIONS OF INSTRUCTORS

A. Robert F. Henderson, Senior Engineer will be the principal instructor. He has 6 years' experience in design and operation of seismic and side scan sonar systems with EG&G. Other related experience and education as per attachment 1.

B. Arthur G. Gerokoulis, Technical Specialist will be the assistant instructor. He has 8 years' experience in the construction of seismic systems and 3 years' experience in construction and operation of side scan and seismic systems.